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SHORT COMMUNICATIONS

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Effect of dietary glycine on the activity of some digestive enzymes in the final instar larvae of *Bombyx mori* L.

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ABSTRACT: The dietary supplementation of the amino acid glycine was found to influence the activity of three key digestive enzymes *viz.*, amylase, protease and sucrase from midgut tissue of final instar larvae of the commercial bivoltine hybrid race CSR18×CSR19 of *Bombyx mori* L. The sucrase activity was noted to be higher than amylase and protease activity. Their activity increased during the active feeding period reaching maximum on the day four for protease and sucrase and on day five for amylase. A sudden rise in the activity of protease and sucrase was noticed on the last day, before the onset of spinning. Amylase responded positively to the dietary glycine supplementation only up to the fourth day (i.e., during the obligatory feeding period). Protease also responded positively to dietary glycine supplementation on day 1 and day 6 of the instar i.e., when its activity in the control larvae was found to be low. Surcase activity was influenced favorably by the dietary glycine supplementation at lower concentration than at higher concentration. These observations indicate that dietary glycine supplementation has a telling effect on the nutritional physiology of the mulberry silkworm, *Bombyx mori* L.

KEYWORDS: *Bombyx mori*, glycine, amylase, protease, surcane

INTRODUCTION

The digestive physiology of *Bombyx mori* solicits greater attention in view of its economic importance. The midgut of this insect is primarily concerned with the secretion of digestive enzymes and the absorption of digested material (Shinbo *et al.*, 1996). Investigations on different enzymes in this silkworm ever since the pioneering work of Matsumara (1934) resulted in the localization and characterization of several digestive enzymes (Kanekatsu, 1973; Eguchi and Iwamoto, 1976; Saranki, 1986;

Jadav and Kallapur, 1988; Yuan *et al.*, 1990; Abraham *et al.*, 1992; Sumida *et al.*, 1994). Dietary supplementation of the amino acid glycine was found to influence the growth of the silkworm resulting increased silk production (Sengupta *et al.*, 1972; Mustafa and El-Karaksy, 1990; Sarker *et al.*, 1995). This paper reports the effect of dietary glycine on the activity of some digestive enzymes in the final instar larvae of the commercial bivoltine hybrid race CSR18×CSIR19 of the mulberry silkworm, *Bombyx mori* L.

MATERIAL AND METHODS

Disease free layings of the silkworm, *B. mori* L. (commerical hybrid race CSR18×CSR19) were obtained and the larvae were raised on fresh leaves of MR_2 variety of mulberry as per standard method (Dandin *et al.*, 2000). Freshly moulted fifth instar larvae were divided in to 12 equal groups to form four triplicates each for control and experimental sets with 0.4, 0.8 and 1.2 per cent glycine supplementation respectively. The larvae in the experimental tray were fed four times a day uniformly with mulberry leaves dipped in glycine solution of the respective concentration prepared fresh by dissolving glycine (Qualigens find chemicals, Mumbai, India) in distilled water. The larvae in the control set were given untreated mulberry leaves simultaneously. The larvae were thus reared at 26 ± 1 °C and 80 ± 10% RH for the entire duration of the fifth instar that lasted for seven days. Sample larvae were picked out from each tray daily and dissected out in ice-cold phosphate buffered saline. The midgut epithelium free from peritrophic membrane and gut contents were collected and homogenized with phosphate buffered saline (Nagata and Kobayashi, 1990). The homogenate was centrifuged at 4 °C at 8000 rpm for 15 minutes and the supernatant was used as the enzyme source (Lakshmikumari *et al.*, 1997).

The quantification of tissue protein was carried out following Lowry *et al.* (1951) using Bovine serum albumen as standard. Amylase activity was measured using Dinitrosalicylic acid reagent following Bernfeld (1955) and Baker (1991). The reaction mixture contained 0.2% soluble starch as substrate, 10 mM Borate buffer of pH 9.2 and enzyme extract. It was incubated at 37°C for 30 min and the reaction was terminated with the addition of the reagent. The colour developed was read at 575 nm and compared with that from maltose hydrate used as standard. Protease activity was assayed following the method of Eguchi and Iwamoto (1976) as outlined by Saranki (1986) using casein as substrate and tyrosine as standard. The incubation was carried out at room temperature in 0.1 M borate buffer of pH 11 and the OD was measured at 660 nm. Sucrase activity was estimated using 0.2% sucrose as substrate in the reaction mixture with 10 mM phosphate buffer of pH 6.8 and by measuring the release of glucose per minute at 30°C (Sumida *et al.*, 1990, 1994). Glucose estimation was done using the dinitrosalicylic acid reagent with dextrose as standard 540 nm. The activity of enzymes are expressed in units defined as the amount of enzyme protein that catalyzed the formation of one μg of the product in a minute from the substrate (Nagaraju and Abraham, 1995).

TABLE 1. Influence of dietary glycine supplementation on the activity of midgut amylase, protease and sucrase in the final instar larvae of *Bomyx mori* L. (CSR18×CSR19)

Day	Enzyme activity@	Concentration of glycine supplemented (%)			
		0.0	0.4	0.6	0.8
0	Amylase	4 ± 2			
	Protease	16 ± 1	–	–	–
	Sucrase	135 ± 12			
1	Amylase	4 ± 1	6 ± 1	5 ± 1	7 ± 2*
	Protease	18 ± 3	21 ± 4	22 ± 3	31 ± 5*
	Sucrase	144 ± 11	225 ± 14*	155 ± 10	189 ± 17*
2	Amylase	8 ± 2	17 ± 3*	22 ± 3*	17 ± 3*
	Protease	21 ± 3	19 ± 4	21 ± 2	24 ± 3
	Sucrase	189 ± 17	262 ± 14*	236 ± 19*	260 ± 22*
3	Amylase	13 ± 3	16 ± 4	38 ± 4*	45 ± 4*
	Protease	45 ± 5	39 ± 3	36 ± 3*	36 ± 4*
	Sucrase	324 ± 19	428 ± 22*	381 ± 19	394 ± 21*
4	Amylase	14 ± 2	18 ± 4	40 ± 3*	51 ± 5*
	Protease	49 ± 5	42 ± 2	37 ± 3*	42 ± 2
	Sucrase	415 ± 32	520 ± 41*	291 ± 27*	485 ± 46
5	Amylase	26 ± 4	25 ± 3	19 ± 3*	18 ± 2*
	Protease	39 ± 4	35 ± 4	35 ± 4	39 ± 5
	Sucrase	291 ± 9	374 ± 23	262 ± 13	151 ± 27*
6	Amylase	22 ± 1	21 ± 1	17 ± 2*	12 ± 4*
	Protease	17 ± 4	32 ± 3*	54 ± 6*	88 ± 7*
	Sucrase	225 ± 18	335 ± 32*	229 ± 26	266 ± 29
7	Amylase	21 ± 2	19 ± 4	16 ± 3*	8 ± 2*
	Protease	66 ± 6	56 ± 7	61 ± 6	66 ± 4
	Sucrase	1230 ± 87	2388 ± 132*	1288 ± 126	1033 ± 98

*Each value is the average of three observations ± SD. @Values expressed as μg maltose, tyrosine and dextrose released/mg/min respectively, for amylase, protease and sucrase activity. *Student '*t*' values for the difference from control significant at 0.05 level.

RESULTS AND DISCUSSION

The activity of the three enzymes from the midgut tissue of *B. mori* during the fifth instar and their response towards the dietary supplementation of glycine are given in Table 1.

Amylase activity

Amylase is one of the key enzymes involved in the digestion of carbohydrates in insects. In *B. mori*, Yokoyama (1959) reported the presence of two different forms of

amylase in digestive fluid and haemolymph. Kanekatsu (1973) purified the amylase of the digestive fluid and studied its kinetics. Abraham *et al.* (1992) noticed that amylase activity of the digestive fluid was 40 fold higher than that of haemolymph. They observed that during the fifth larval stadium of this silkworm, the amylase activity increased gradually reaching the peak on the fourth day followed by a decrease towards the onset of spinning. In the present study the midgut amylase activity was found to follow a similar pattern but showing maximum activity on day 5 in the control larvae. The activity of this enzyme increased with the increase in the dietary glycine supplementation up to day 4, i.e., during the obligatory feeding period of the instar and *vice versa* during the rest of the days.

Protease activity

Protease activity in the silkworm *Bombyx mori* was reported to be high in the midgut tissue on day 4 of the fifth instar (Jadav and Kallapur, 1988; Lakshmikumari *et al.*, 1997). In the present study also the activity of midgut protease increased gradually, reaching maximum on day 4 followed by a decrease thereafter. However a spurt in the activity was noticed on day 7 before the onset of spinning. This observation also was in line with that of Lakshmikumari *et al.* (1997). With reference to dietary glycine supplementation, an increase in protease activity was observed on the first and sixth day, i.e., when the activity of this enzyme was at its low ebb in control and no significant change in enzyme activity was noticed during the other days.

Sucrase activity

The activity of sucrase showed a steady increase during the course of the instar with a steep rise on the last day before the onset of spinning. Sumida *et al.* (1990) studied the changes in the kinetic properties and total activity of midgut sucrase in *Bombyx mori*. They found the activity of sucrase to correspond to the feeding periods and reported one minor and two major peaks during the fifth instar. The minor peak occurred during the obligatory feeding period and the two major peaks were found to correspond to active feeding period and spinning stage respectively. Yuan *et al.* (1990) isolated three types of soluble sucrase from the midgut of nine strains of *Bombyx mori* and found that hybrid strains had higher activity. The observation of higher sucrase activity when compared to amylase and protease in the present study therefore was reasonable as it was from a bivoltine hybrid race. Further, the increase in sucrase activity was found to be more with the supplementation of glycine at lower concentration than at higher concentrations.

Digestive enzymes play a major role in the body of insects by converting complex food materials in to micromolecules necessary to provide energy and metabolites (Wigglesworth, 1972). As in other animals the production of midgut enzymes in insects is not a continuous process and the level varies in relation to moulting and food intake (House, 1965). Fisk and Sambaugh (1952) had analyzed various factors responsible for the stimulation of enzyme secretion in the midgut of *Aedes aegipti* and found secretogogue mechanism to stimulate the secretion of protease and invertase.

Dadd (1961) suggested both secretogogue and mechanical stimuli to effect the secretion of midgut enzymes in *Tenebrio moliter*. In the midgut of *Locusta migratoria* the secretion of proteinase and invertase was stimulated by the intake of food (Khan, 1964). Ishaaya *et al.* (1971) while working on protease and amylase activities in the larvae of *Spodoptera litoralis* showed that certain protein factors present in the food stimulate digestive enzymes probably through hormonal mechanism. A positive linear correlation was obtained between protease activity of midgut homogenates of *Rhodnius prolixus* and the protein content of the blood consumed (Garcia and Garcia, 1977). Muraleedharan and Prabhu (1977) had noticed that although the median secretary cells appeared to stimulate food intake, the quantity and quality of food ingested stimulated both the secretion and activity of enzymes in the midgut of *Dystercus cingulatus*. The observation of dietary glycine influencing the activity of midgut enzymes in the present study may be due to secretogogue effect and finds support from the report that the cumulative absorption ratio for glycine is high along the entire length of the midgut of silkworm, *Bombyx mori* when compared to other amino acids (Shinbo *et al.*, 1996). Such an inducement on the activity of digestive enzymes by dietary glycine supplementation can well be exploited in augmenting silk production.

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Reproductive behaviour of *Hyblaea puera* Cramer (Lepidoptera: Hyblaeidae)

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ABSTRACT: Reproductive behaviour of the teak defoliator, *Hyblaea puera* Cramer (Lepidoptera: Hyblaeidae) was studied under laboratory conditions. The pre-mating period of both sexes of the moths was one day. Female was monogamous, whereas a male mated with more than one female during its lifespan. Mating occurred during the second half of the night. The peak period of mating was 01.00–04.00 hr. A characteristic courtship behaviour was exhibited by both sexes of the moths. Pre-oviposition period (after mating) was 18–24 hr. Oviposition occurred between sunset and midnight. The mean oviposition period was 7 days. The number of eggs laid varied between 287–606 with an average of 434. The number of eggs laid was maximum on the first day of oviposition.

KEYWORDS: *Hyblaea puera*, mating, oviposition, fecundity, teak defoliator

INTRODUCTION

The teak defoliator, *Hyblaea puera* Cramer (Lepidoptera: Hyblaeidae) is recognised as the most serious pest of teak in India (Beeson, 1941; Nair *et al.*, 1985). Beeson (1941) gave a general account of biology and ecology of this pest. However, no detailed information is available on its reproductive behaviour. Basic data on different aspects of reproductive behaviour are important pre-requisites for a proper understanding of the population dynamics of the pest and for designing and evaluating control strategies. Hence, in the present study data were collected on mating, courtship and oviposition behaviour.

MATERIALS AND METHODS

Insect culture

The initial stock of insects for raising a laboratory cultures was obtained from teak plantations in Nilambur. The moths were fed with 10% honey solution. The larvae up

to third instar were reared on teak leaves and there after on an artificial diet (Mathew *et al.*, 1990) On emergence, the moths were sexed on the basis of the morphological features of their legs. The hind tibia of male is narrow and without long hairs along its outer side. The hind tibia of female is distinctly broader than that of male and is provided with dense long hairs along its outer side. In male, attached close to the base of the hind coxa is a white elongate sac, which encloses a brush organ. The brush organ consists of several elongate hairs kept together and having their origin at the base of hind tibia. When viewed from the ventral side of the moth, a white sac can be clearly seen one on either side of the abdomen. After sexing, the males and females were kept in separate glass bottles (17 cm × 17 cm). The date of emergence of each moth was recorded and those emerged on a particular date were kept together. The colony was maintained at room temperature, 25 °C–32 °C and light: dark cycle of about 12 : 12 h.

Experimental design of the study

Mating and Oviposition behaviour

Preliminary observations were made to ascertain whether *H. puera* mates during day or night. To find out the optimum time of mating, 35 pairs of moths were directly observed during the scotophase between 18.00 and 06.00 h. Each pair was kept in a glass bottle (17 cm × 7 cm) with the mouth of the bottle covered with a muslin cloth. Observations were taken at half an hour interval and the time of mating of each pair was recorded. A 15 W lamp covered with thick white cloth provided sufficient light to make observations without disturbing the normal activities of the moths.

Experiments were conducted to find out the optimum age at which the males and females mated. Males and females in the age group of zero hour (immediately after emergence) and above were used in the study. In studies on the sexual maturity, moths of at least 5 days old were used. When successful mating occurred, date and time of mating were recorded. Each pair was observed till mating occurred or till the experimental male/female was ten days old.

The ability of the male moths to mate with and inseminate more than one female either on successive nights or in a multichoice situation with several females in the same night was investigated. To study the first aspect, 40 males of 3 to 4 days old were used. Each male was provided with a virgin female and allowed a mating time of 5 h between 01.00 and 06.00 h. After the experiment the female of each pair was transferred to another bottle for oviposition. Thus each male was provided with one virgin female every successive night till its death. Mating was confirmed based on whether the females exposed to a particular male laid fertile eggs. The experiment was replicated thrice.

To study the second aspect, 10 unmated males of 3 to 4 day old were used. Each male was provided with three virgin females (5 days old) in a glass bottle during the scotophase and observed between 01.00 h and 06.00 h. After the experiment the three females from each container were transferred to three separate bottles, and observed for laying fertile eggs. As only mated females laid fertile eggs, it was possible to find out the number of females with which a male successfully mated on a particular night.

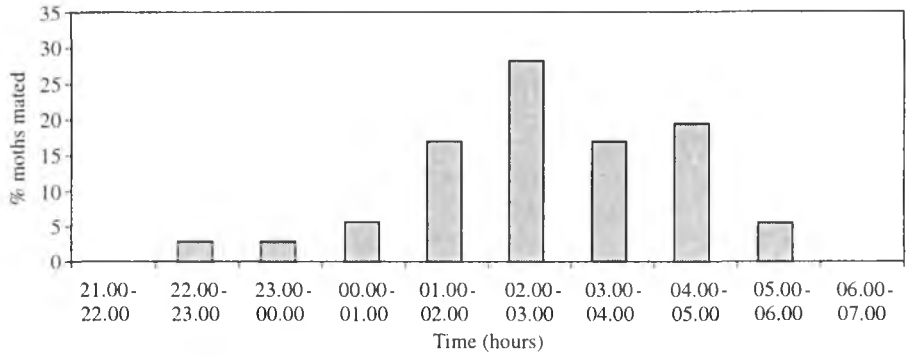

FIGURE 1. Time of mating of *H. puera*.

Fifty pairs of sexually mature adults were used in a series of observations on courtship behaviour. Each pair was held in a glass bottle (20 cm × 10 cm) and the activities of male and female were observed and recorded. Observations were made under dim light between 01.00–06.00 h—the normal mating period.

Preoviposition period, time of oviposition, duration of oviposition, fecundity were recorded and substratum preference for oviposition was studied Mated females were individually maintained in glass bottles covered with muslin cloth (oviposition chamber) and fed with 10% honey solution. Observations were taken at hourly interval and the time of oviposition was recorded. To record duration of oviposition the females were kept under observation till their death and data on oviposition were recorded daily. Fecundity was estimated by counting the eggs laid by each female during its lifetime. The adults were maintained in the laboratory under a light : dark cycle of 12 : 12 h.

RESULTS

Mating behaviour

Time of mating

Mating activity in *H. puera* was found restricted to second half of the scotophase, between 01.00 to 05.00 h. The peak period of mating was between 02.00 to 03.00 h. In very rare cases some pairs mated between 22.00–01.00 h and 05.00–06.00 h (Fig. 1).

Sexual maturity

The male moths did not show mating activities until they became 1 day old. Out of the 30 males studied, 80% mated at the age group of 1–4 days indicating it as the peak period of mating. Within this age group highest percentage of males mated at the age of 1 day (33%). Among the test males 14 per cent did not involve in mating throughout their life period.

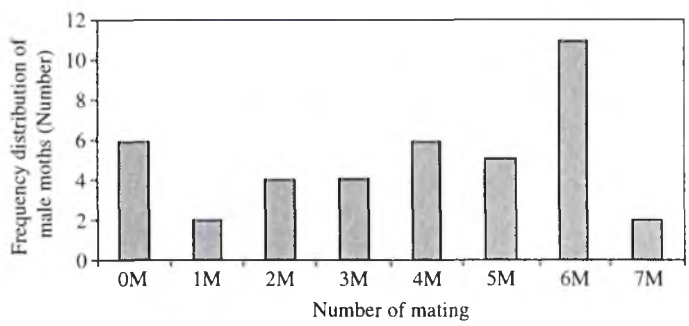

FIGURE 2. Frequency distribution of 40 males according to the number of mating performed during the life span.

The female moth was found to be sexually receptive at the age of one day. The peak mating age group was 1–4 days and the peak age was 3 days (28.5%). Within this age group highest percentage of males mated at the age of 1 day (29%). Twenty six per cent of the females did not mate at all. Mating was found to take place even in the case when females more than ten days old were provided with a male partner. In one instance a 18-day-old female successfully mated which is the maximum mating age recorded.

Mating capacity

Female moths mated only once in their lifespan. The number of mating performed by individual males during their life span is presented in Fig. 2. The highest frequency was six mating. Considerable variation was noted in the number of females successfully inseminated by individual males with a maximum of seven and a peak of six. Out of the 40 males observed, about 20 per cent remained unmated during the observation period of two weeks.

Multi-choice test revealed that a male was able to mate with only one female in a night. Out of the ten males observed, one female did not mate at all and six mated on all the three days and three mated only on two days.

Courtship behaviour and mating

Sexually active males exhibited a characteristic courtship behaviour, which involved the following steps in a sequential order. Rapid movements within the cage including running or flying; Periodic fluttering of wings and wing expansion; Raising of body on hind legs to assume a standing position with head touching the floor; Releasing the hair brushes located on the hind tibia and keeping it opened, fan like; Chasing the female; Raising the forewings above the abdomen in 'V' shape; A circling movement near the female prior to mating.

The female courtship behaviour included the following steps: Rapid movements including flight; Opening and vibrating the wings at intervals keeping the antennae

raised up; Standing erect on hind legs and raising wings above abdomen to assume 'V' shape; Assuming the normal position at the end of the above steps.

Though in general the males and females exhibited all the various steps of their courtship behaviour, some moths mated at least omitting a few steps. In very rare cases, instant mating occurred immediately after caging without exhibiting any courtship behaviour.

At the end of the courtship behaviour the male approached the female and exhibited either a clockwise or anticlockwise circling movement and finally remained quiet facing the back of the female. At this stage the male kept its wings raised up. The male then took a 90° anticlockwise turn and extended and curved its abdomen towards the female genitalia and established genital contact. Subsequently the male took another 90° anticlockwise turn and closed its wings and took the normal position. Thus in copulation the male and female assumed a back-to-back position. The duration of copulation varied between 50–220 min (Mean 104 min).

Once the copulation was over the partners separated for which female usually took the initiative. However, some pairs were occasionally seen in copulation during day time as the male had not succeeded in disengaging its genital apparatus presumably after initiating copulation during the preceding night.

Oviposition behaviour

As a rule, a female *H. puera*, which mated during the early morning hours of a particular day, laid its first batch of eggs on the same day evening, the preoviposition period being 18–24 h after mating. Normally oviposition started at sunset and prolonged up to midnight. Major share of the eggs was laid before midnight.

Preference for substratum for oviposition

Under laboratory condition the substrata available for the moths to lay eggs were the inner surface of the glass container and the lower surface of the white cotton cloth used to close the container. Presence of host (teak) leaves in the container was not required to trigger oviposition. Eggs were laid both on the glass surface as well as on the white cotton cloth cover. Observation on the egg laying pattern of 26 females indicated that the moths preferred to lay eggs on the cloth (C) rather than on the glass surface (G). The percentage of moths, which laid eggs during their first day of oviposition on C, G and C + G, were 58, 27 and 15 respectively. Apparently the moths preferred to lay eggs on cotton probably because of its rough texture which resembles the texture of teak leaf.

Duration of oviposition

The duration of oviposition of *H. puera* varied between 1–11 days with an average of 7 days being the median (Table 1). However, only about 15 per cent of the females were observed laying eggs for more than one week. Once the oviposition started, egg laying occurred every day until the end of the oviposition period. In a small percentage of the females (25%) oviposition period was discontinuous as no eggs were laid on

TABLE 1. Frequency distribution of 92 females according to their Oviposition period

Frequency of females observed	Duration of oviposition (days)
12	1
10	2
12	5
18	6
23	7
9	8
4	9
3	10
1	11

certain days. However the total number of eggs laid by such moths was comparable with that of normal moths.

The life span of the *H. puera* females (mated) varied from 3 to 28 days with an average of 13 days. In the case of a female, which mated at the age of one day, egg laying was completed during the average oviposition period of 6–7 days. Thus the moth could complete its oviposition before it crossed the average lifespan. However, when mating was prevented under laboratory conditions oviposition also got delayed. Data based on 14 females indicated that a delay of one week in involving in mating and subsequent delay in oviposition did not affect the normal oviposition period as well as fecundity. There was no correlation between mating time (age) and the oviposition period as well as the fecundity ($r = 0.273$ and 0.0010 respectively).

Fecundity

Under laboratory conditions the total number of eggs laid by *H. puera* female varied from 287 to 606 with an average of 434 ($n = 31$). The number of eggs laid was maximum on the first day of oviposition and thereafter the number decreased progressively.

DISCUSSION

A single peak period of mating per night was observed in *H. puera*. Similar observations have been reported in the noctuid, *Anadevidia peponis* (Sasaki, 1976) and the pyralid, *Eutectona machaeralis* (Gopakumar and Prabhu, 1986). However, two peak periods of mating is also known in some moths as reported in the case of Jute hairy caterpillar *Diacrisia obliqua* (Islam and Alam, 1973).

As the male–female ratio of *H. puera* is almost the same, male polygamy is advantageous from the point of its application in pest management programmes involving manipulation of the males.

Among Lepidopterans, females of many species exhibit a typical calling behaviour by lifting the wings and curving the abdomen and by protrusion and retraction of terminal abdominal segments during which it apparently releases the pheromone from the exposed glands to attract the male (Islam and Alam, 1973; Ellis and Brimacombe, 1980). A similar calling behaviour was not observed in *H. puera*. It is possible that the calling behaviour was not conspicuous in *H. puera* as the experimental moths were confined to small glass containers having limited space and the male was already in close range of the female and even visual cues could serve the purpose.

Display of hairbrushes observed in male *H. puera*, as part of courtship behaviour, has already been reported in a number of species of moths including the forest pest, *Eutectona machaeralis* (Gopakumar and Prabhu, 1986). The association of the display of hair brushes with male pheromone dispersal has been reported in the oriental fruit moth, *Grapholitha molesta* (Baker *et al.*, 1981). Gopakumar and Prabhu (1986) also reported a similar possibility of pheromone dispersal through hair pencil display in *E. machaeralis*.

The observation on the oviposition period of *H. puera* as about one week and that most of the eggs are laid during the first half of the oviposition period are in conformity with the report on this species from Thailand (Lakanavichian and Napompeth, 1990). Though oviposition occurred daily during the oviposition period, unpublished field data (K. Mohanadas, KFRI, personal communication) suggest that the moths do not oviposit in the same locality continuously. During the peak pest incidence period, larvae observed in a particular locality belonged to the same age group. Continuous egg laying in the same locality would have resulted in forming a larval population of different larval instars there. Hence it appears that the moths after laying eggs in one locality for one or two days move to another locality to continue oviposition. This could also be true as the larval population located in two distantly separated patches of teak plantations during the early part of the infestation period usually differed in their age at least by 2–3 days. The oviposition behaviour observed also substantiate the migratory behaviour of *H. puera* postulated by Nair and Sudheendrakumar (1986).

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A new species of *Crematogaster* (Hymenoptera: formicidae: myrmicinae) from India

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ABSTRACT: A new species of *Crematogaster, C. urvijae* sp. nov., is described and illustrated. The species differs remarkably from other Indian species described hitherto.

KEYWORDS: New ant species, *Crematogaster*, India

Genus *Crematogaster* Lund, 1831 is represented by about 417 species over the globe, and by 17 valid species from India (Bolton, 1995). While studying Formicidae from North–West India, this new species of *Crematogaster* has been discovered and it differs from all other Indian species listed in Bingham's Fauna (1903) and Bolton's Catalogue (1995) quite remarkably and can be easily separated from these.

***Crematogaster urvijae* sp. nov.**

Holotype worker (Major) (Figs. 4–6 and 9)

Length: 5.33 mm; Head length: 0.58 mm; Head width: 0.82 mm; Scape length: 0.43 mm; Scape index: 52.4; Eye diameter: 0.16 mm; Pronotal width: 0.60 mm; Alitrunk length; 0.66 mm; Cephalic index: 141.3.

Head (Fig. 6 and 9)

Broader than long; sides converging from edge of clypeal margin upto eyes; posteriorly oval with occipital margin straightening; mandibles with 4 teeth; palp formula 5, 4; anterior margin of clypeus subacuminate; posterior margin transverse; frontal carinae indistinct diverging posteriorly, just touching anterior eye margin; antennal scrobe feebly indicated; pit like area marked in centre of vertex, marked by two feeble carinae which broaden anteriorly and converge posteriorly enclosing a shallow groove; antennae 11-jointed; club formed by last two apical joints; joint 9 wider than longer than remaining joints except first one which is longer; scape narrow anteriorly, broadening posteriorly; almost reaching upto upper margin of eye; eyes lateral; placed slightly

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above mid-line; whole of head with anterior clypeal margin, mandibles covered with long hairs; head longitudinally striate (rugose) at cheeks and near inner margin of eyes, finely punctured all over.

Thorax, petiole and post-petiole (Figs. 4 and 5)

Pronotum with anterior angles rounded; narrowing posteriorly; confluent with mesonotum; mesonotum flat as seen from above sloping posteriorly; meso-metanotal furrow distinct; metanotal spines thick at base diverging posteriorly; spines sub-equal to metanotum; pro-mesonotum forming same plain, metanotum very low as compared to pro-mesonotum; petiole almost rectangular, flat from above with anterior margins rounded; longer than broad; post-petiole attached to petiole by a tubercle followed by two larger posterior tubercles joining gaster; pro-mesonotum with few longitudinal striations; reticulate; metanotum irregularly rugose; petiole-post-petiole, finely punctured; whole of thorax with scattered decumbent hairs. Legs: coxae swollen, femora flat; covered with scattered hairs.

Gaster

Gaster massive; cordate and elongate; finely punctured all over; covered with scattered hairs; at level of pro-mesonotum.

Head, thorax, pedicel yellowish brown; mandibles, apical segment of antennae with more brownish tinge; legs yellowish; gaster with alternate yellow and brown bands; apical segments completely brown.

Paratype worker (Minor) (Figs. 1–3)

Length: 2.2 mm; Head length: 0.35 mm; Head width: 0.48 mm; Scape length: 0.16 mm; Scape index: 33; Eye diameter: 0.09 mm; Pronotal width: 0.33 mm; Alitrunk: 0.55 mm; Cephalic index: 137.

Smaller in size as compared to major; differs from major as; pronotum with more prominent anterior angles head, thorax and abdomen finely punctured; antennae entirely yellowish; mandibles with a faint tinge of brown.

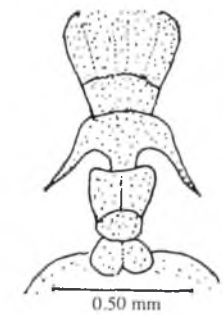
Paratype female (de alate) (Figs. 7 and 8)

Length: 8 mm; Head length: 0.82 mm; Head width: 0.90 mm; Scape length: 60 mm; Scape index: 66.6; Eye diameter: 0.28 mm; Pronotal width: 0.99 mm; Alitrunk: 1.65 mm; Cephalic index: 109.

Head like major but with prominent ocellii; pronotum converging anteriorly; pro-mesonotum marked by black impression; metanotal spines reduced; petiole tubercles reduced; appendix small; abdomen long.

Holotype

Worker (Major); India, Patiala, Punjabi University Botanic garden; 249 mtrs; 30.20 N, 76.25 E; 21. IV 2000; Bharti, H.



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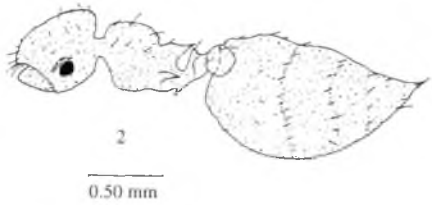

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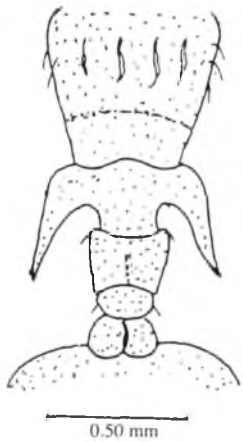

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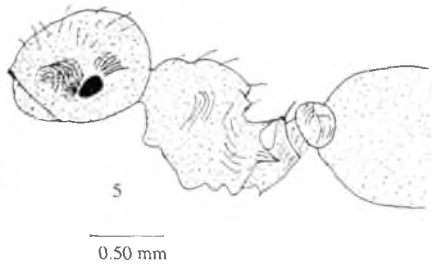

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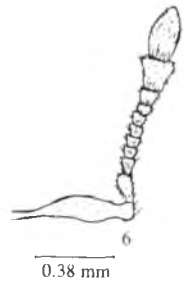

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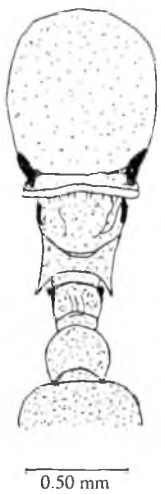

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8

9

Paratypes

15 majors, 12 minors, one de alate female with same data as of holotype.

Habitat

No foraging worker was found out side nest. Nest in loose soil, 5–6 cms deep at base of *Dalbergia* tree. When excavated workers started running in all directions. Along this species, *Aenictus pachycerus* was also collected from same nest.

Discussion

Crematogaster urvijae sp. nov. is somewhat allied to *Crematogaster artifex* Mayr, due to (i) scape of antenna not crossing posterior margin of head (ii) metanotal spines divergent backwards (iii) petiole with anterior margins rounded; but can be easily separated from this by; head finely longitudinally striate all over in *artifex*; striate anteriorly, but finely punctured all over in *urvijae* sp. nov; pro-mesonotum not highly elevated in *artifex*, but so in *urvijae*; pro-mesonotal suture distinct in *artifex*, indistinct in *urvijae* sp. nov; petiole not trituberculate in *artifex*; trituberculate in *urvijae* sp. nov; abdomen smooth in *artifex*; but finely punctured in *urvijae* sp. nov; apart from this both species differ strikingly in colour pattern, which is fairly constant in *urvijae* sp. nov.

Etymology

The species is named after the daughter of author, Urvija; who has been a moral support throughout the course of present studies.

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Influence of some plant growth regulators (PGR) on biochemical profile in the larvae of melon fruit fly *Bactrocera cucurbitae* (Coquillett) (Diptera: Trypetidae)

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ABSTRACT: When the larvae of melon fruit fly, *Bactrocera cucurbitae* were treated with plant growth regulators (PGRs)—Gibberellic Acid (GA_3), Indole-3-Acetic Acid (IAA), kinetin and coumarin, there were quantitative changes in the proteins and carbohydrates and in the activities of hydrolytic enzymes which are involved in detoxification, moulting and metamorphosis. The total protein level increased after kinetin and GA_3 treatment, but was affected after treatment with coumarin and IAA. The esterase activity was stimulated by coumarin and GA_3, but inhibited by kinetin under prolonged treatment and was unaffected by IAA treatment. Treatment with coumarin and IAA stimulated the activity of acid phosphatase significantly. Kinetin treatment stimulated the acid phosphatase activity only at 118 h of larval age and GA_3 treatment suppressed it. The activity of alkaline phosphatase was severely inhibited after treatment with all the PGRs. The content of free sugar decreased after coumarin and kinetin treatment but increased slightly after GA_3 and IAA treatment. The contents of other sugars, i.e. glycogen and trehalose were reduced after treatment with all the PGRs.

KEYWORDS: Plant growth regulators, melon fruit fly, *Bactrocera cucurbitae*, enzyme activity

INTRODUCTION

Most of the herbivorous insects have synchronized growth and developmental patterns with the physiological status of their host plants. It is, however, interesting to observe that a number of plant growth regulators influence growth and development of the associated insects (Fischer *et al.*, 1987). We reported earlier that plant growth regulators (PGRs) such as Gibberellic Acid (GA_3), Indole-3-Acetic Acid (IAA), kinetin and coumarin caused adverse effects on the growth, development and

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reproduction of melon fruit fly, *Bactrocera cucurbitae*, a serious pest of fruits and vegetables in tropical countries (Kaur and Rup, 1999, 2000; Rup *et al.*, 2000). These PGRs have been included in IPM programme of some pests of economic importance (Fischer *et al.*, 1987), but their metabolism and mode of action is yet to be ascertained. The fluctuations in the enzyme systems and action of growth hormones result in the abnormal growth and developmental patterns due to disturbances in the metabolism and metamorphosis. The contents of proteins, carbohydrates and lipids in an animal's body are disturbed greatly. The present investigation was aimed at assessing the influence of these PGRs on contents of proteins and carbohydrates and activity of hydrolytic enzymes during the growth and development of *B. cucurbitae* larvae.

MATERIALS AND METHODS

The influence of four PGRs viz., GA_3, IAA, kinetin and coumarin on the biochemical entities—total proteins, esterases, acid phosphatase, alkaline phosphatase, glucose, glycogen and trehalose was investigated on 70 h old larvae of *B. cucurbitae*. The larvae were reared on an artificial medium prepared according to Srivastava (1975), and contained casein, sucrose, vitamins, chloramphenicol, *p*-hydroxybenzoate, water and agar–agar as ingredients. Sub-lethal doses of the PGRs (125 ppm of coumarin; 625 ppm of GA_3 and kinetin and 3125 ppm of IAA) were selected for application on the basis of morphogenetic studies carried out earlier. The estimations for all the biochemical entities were done after permitting ad lib feeding on treated medium at three intervals (24, 48 and 72 h) to 70 h old larvae. All the experiments were conducted in the culture room/BOD incubators maintained at constant temperature of $25 \pm 2\,^{\circ}C$ and 70–80% RH.

Proteins were extracted by homogenizing larvae (1% w/v) in phosphate buffer (0.1 M, pH 7.2) (Burcombe and Hollingsworth, 1970) and estimated according to the method of Lowry *et al.* (1951). The activity of esterases was determined by the method of Katzenellenbogen and Kafatos (1971). The activities of Acid Phosphatase (AcP) and Alkaline Phosphatase (AkP) were determined by the method given by Mc Intyre (1971). The glucose was estimated by Anthrone method (Mokrasch, 1954). The extraction of storage sugar (glycogen) was done by homogenizing the larvae in a solution of potassium hydroxide (30% w/v), sodium sulphate and 95% ethanol (Good *et al.*, 1933) and it's content was quantified by adopting the phenol-sulphuric acid method (Montgomery, 1957). The trehalose (haemolymph sugar) was extracted using 0.1 N sulphuric acid and 6 N sodium hydroxide (Wyatt and Kalf, 1975; Woodring *et al.*, 1977) and it was estimated by using phenol (5% w/v) and concentrated sulphuric acid (Dubois *et al.*, 1956).

RESULTS AND DISCUSSION

Treatment with GA_3 (625 ppm) for 24, 48 and 72 h increased the protein content significantly ($P < 0.001$) by one and a half times as compared to that in the control (Table 1). The GA_3 enhanced the activities of esterases upto 118 h age after 48 h

TABLE 1. Content/activity levels of biochemical entities in *B. cucurbitae* larvae under the influence of GA_3 (625 ppm)

Biochemical entities	Treatment	Content/activity (mean ± SE) Age of larvae[1] and treatment duration[2]			
		70 h[1] (0 h)[2]	94 h[1] (24 h)[2]	118 h[1] (48 h)[2]	142 h[1] (72 h)[2]
Total proteins	Control	18.49 ± 0.47	18.81 ± 0.18	20.78 ± 0.57	21.11 ± 0.50
($\mu g\ mg^{-1}$)	GA_3	—	28.38 ± 0.34^{d}	31.90 ± 0.23^{d}	31.58 ± 0.07^{d}
Esterases	Control	34.79 ± 1.29	37.58 ± 4.23	38.43 ± 3.67	51.88 ± 1.22
($\mu M\ Mg^{-1}$)	GA_3	—	64.00 ± 7.37^{a}	52.73 ± 0.00^{b}	47.64 ± 0.00^{a}
AcP	Control	7.56 ± 0.01	13.32 ± 0.03	11.96 ± 0.18	9.24 ± 0.04
($\mu M\ mg^{-1}$)	GA_3	—	7.28 ± 0.07^{d}	11.11 ± 0.96^{ns}	7.52 ± 0.01^{d}
AkP	Control	15.86 ± 0.09	12.42 ± 0.16	8.94 ± 0.08	12.60 ± 0.17
($\mu M\ mg^{-1}$)	GA_3	—	1.20 ± 0.07^{d}	2.20 ± 0.15^{d}	2.44 ± 0.08^{d}
Glucose	Control	19.30 ± 0.47	18.46 ± 0.60	23.92 ± 0.60	25.29 ± 0.81
($\mu g\ mg^{-1}$)	GA_3	—	20.13 ± 1.58^{ns}	24.66 ± 0.10^{ns}	28.21 ± 0.23^{ns}
Glycogen	Control	6.46 ± 0.17	9.00 ± 0.12	10.26 ± 0.06	13.11 ± 0.46
($\mu g\ mg^{-1}$)	GA_3	—	0.66 ± 0.01^{d}	2.38 ± 0.06^{d}	3.48 ± 0.06^{d}
Trehalose	Control	16.58 ± 0.51	24.30 ± 0.23	26.95 ± 0.20	35.22 ± 1.13
($\mu g\ mg^{-1}$)	GA_3	—	13.44 ± 0.00^{d}	14.96 ± 0.57^{d}	17.33 ± 0.00^{d}

of treatment ($p < 0.02$) but at the age of 142 h, at prepupal stage after 72 h of treatment, there was a significant ($p < 0.05$) decline. It suppressed the activity of AcP and AkP as well as the levels of specific sugars (glycogen and trehalose) significantly ($p < 0.001$), whereas it increased the level of glucose (Table 1). The findings of Rup *et al.* (1998b) and Rup and Kaur (1993) on the effects of GA_3 on proteins, glucose, glycogen, AcP and AkP in banana fruit fly, *Zaprionus paravittiger* corroborate the present results. However, contradictory effects of natural gibberellin (GA_3) as well as of synthetic gibberellins like Alar B-9 and maleic hydrazide on the esterases have been observed by Rup and Kaur (1993) and Rup *et al.* (1999) in *Z. paravittiger* and mustard aphid, *Lipaphis erysimi* respectively. The insect growth regulator JH III, which has similar chemical configuration as that of GA_3, has also been reported to increase the protein content in *Oncopeltus fasciatus* (Bassi and Feir, 1971) and *Bomyx mori* (Chen *et al.*, 1982). This led Visscher (1980) to infer that GA_3 might have influenced the protein synthesis via some hormonal pathways. As esterases are involved in the development and metamorphosis of insects by regulating the titres of developmental hormones (Sparks and Hammock, 1980), the increased activity of esterases in early larvae by the application of GA_3 in the present case suggested that it might be interfering in the normal metamorphosis through esterases. Moreover, suppression in AcP activity and decrease in the glycogen content by GA_3 could be due to their involvement in the active mobilization of glycogen with phosphorylation at the acid range as suggested by Pant and Lacy (1969).

The biochemical studies on effects of IAA (3125 ppm) application showed that it neither influenced the protein content nor esterase activity (Table 2). It, on the other

TABLE 2. Content/activity levels of biochemical entities in *B. cucurbitae* larvae under the influence of IAA (3125 ppm)

Biochemical entities	Treatment	Content/activity (mean ± SE) Age of larvae and treatment duration			
		70 h[1] (0 h)[2]	94 h[1] (24 h)[2]	118 h[1] (48 h)[2]	142 h[1] (72 h)[2]
Total proteins	Control	18.49 ± 0.47	18.81 ± 0.18	20.78 ± 0.57	21.11 ± 0.50
(μg mg^{-1})	IAA	—	18.32 ± 0.07^{ns}	19.06 ± 0.18^{ns}	20.37 ± 0.12^{ns}
Esterases	Control	34.79 ± 1.29	37.58 ± 4.23	38.43 ± 3.67	51.88 ± 1.22
(μM mg^{-1})	IAA	—	34.30 ± 1.79^{ns}	35.88 ± 0.69^{ns}	53.09 ± 2.36^{ns}
AcP	Control	7.56 ± 0.01	13.32 ± 0.03	11.96 ± 0.18	9.24 ± 0.04
(μM mg^{-1})	IAA	—	22.00 ± 0.08^{d}	15.08 ± 0.01^{ns}	16.44 ± 0.18^{d}
AkP	Control	15.86 ± 0.09	12.42 ± 0.16	8.94 ± 0.08	12.60 ± 0.17
(μM mg^{-1})	IAA	—	5.66 ± 0.18^{d}	5.04 ± 0.06^{d}	5.28 ± 0.04^{d}
Glucose	Control	19.30 ± 0.47	18.46 ± 0.60	23.92 ± 0.60	25.29 ± 0.81
(μg mg^{-1})	IAA	—	24.49 ± 0.23^{c}	24.36 ± 2.15^{ns}	26.54 ± 0.18^{ns}
Glycogen	Control	6.46 ± 0.17	9.00 ± 0.12	10.26 ± 0.06	13.11 ± 0.46
(μg mg^{-1})	IAA	—	2.19 ± 0.05^{d}	6.44 ± 0.48^{d}	17.76 ± 0.56^{a}
Trehalose	Control	16.58 ± 0.51	24.30 ± 0.23	26.95 ± 0.20	35.22 ± 1.13
(μg mg^{-1})	IAA	—	18.90 ± 0.30^{d}	19.74 ± 0.50^{d}	35.07 ± 0.90^{ns}

hand, reduced the storage sugars ($P < 0.001$) in the early larval stages (94 and 118 h old), which recovered to normal state later on. It increased the AcP activity and suppressed the AkP activity ($P < 0.001$) (Table 2). The present observations regarding AcP and AkP activity corroborate the patterns observed in *Z. paravittiger* and *L. erysimi*, respectively (Rup and Kaur, 1993; Rup and Dhillon, 1999). The ability of metabolize IAA to non-toxic substances has been advocated in the bug, *Lygus disponsi*, which feeds on plant parts rich in auxins (Hori, 1971, 1980). The increased activity of AcP in *B. cucurbitae* might be due to its involvement in the metabolism of IAA.

Kinetin treatment (625 ppm) increased the protein content ($P < 0.01$). It stimulated esterase activity ($P < 0.05$, $P < 0.02$) initially, but reduced it ($p < 0.02$) under prolonged exposure (Table 3). Similarly, low esterase activity has been observed in *L. erysimi* after prolonged treatment of its nymphal instars with cytokinetin (Rup *et al.*, 1999). The kinetin treatment induced fluctuations in the AcP activity as after 24 h of treatment the activity got suppressed and then enhanced after 48 h of treatment, but the activity was at par in the controls after 72 h of treatment. The activity of AkP and the contents of all the three sugars were adversely affected by the kinetin treatment. It could be inferred that kinetin treatment stimulated the protein synthesis at the expense of carbohydrates. The fluctuation in the AcP activity suggested their involvement and the suppression in AkP activities suggested their non-involvement in kinetin metabolism or application of kinetin might be interfering in the synthesis of these enzymes.

Treatment of 70 h old larvae with coumarin (125 ppm) did not change the protein content, reduced the contents of all the three sugars and suppressed the AkP activity

TABLE 3. Content/activity levels of biochemical entities in *B. cucurbitae* larvae under the influence of kinetin (625 ppm)

Biochemical entities	Treatment	Content/activity (mean ± SE) Age of larvae and treatment duration			
		70 h[1] (0 h)[2]	94 h[1] (24 h)[2]	118 h[1] (48 h)[2]	142 h[1] (72 h)[2]
Total proteins	Control	18.49 ± 0.47	18.81 ± 0.18	20.78 ± 0.57	21.11 ± 0.50
(μg mg^{-1}	Kinetin	—	13.42 ± 1.75^{ns}	28.13 ± 0.36^{c}	29.29 ± 0.82^{c}
Esterases	Control	34.79 ± 1.29	37.58 ± 4.23	38.43 ± 3.67	51.88 ± 1.22
(μM mg^{-1})	Kinetin	—	50.91 ± 6.89^{a}	60.97 ± 3.52^{b}	46.18 ± 8.40^{b}
AcP	Control	7.56 ± 0.01	13.32 ± 0.03	11.96 ± 0.18	9.24 ± 0.04
(μM mg^{-1})	Kinetin	—	10.56 ± 0.36^{b}	14.88 ± 0.00^{ns}	9.44 ± 0.25^{ns}
AkP	Control	15.86 ± 0.09	12.42 ± 0.16	8.94 ± 0.08	12.60 ± 0.17
(μM mg^{-1})	kinetin	—	6.80 ± 0.11^{d}	6.98 ± 0.03^{d}	0.49 ± 0.00^{d}
Glucose	Control	19.30 ± 0.47	18.46 ± 0.60	23.92 ± 0.60	25.29 ± 0.81
(μg mg^{-1})	Kinetin	—	8.59 ± 0.21^{d}	16.54 ± 0.55^{c}	14.10 ± 0.91^{c}
Glycogen	Control	6.46 ± 0.17	9.00 ± 0.12	10.26 ± 0.06	13.11 ± 0.46
(μg mg^{-1})	Kinetin	—	0.63 ± 0.02^{d}	0.47 ± 0.03^{d}	0.58 ± 0.02^{d}
Trehalose	Control	16.58 ± 0.51	24.30 ± 0.23	26.95 ± 0.20	35.22 ± 1.13
(μg mg^{-1})	Kinetin	—	3.99 ± 0.07^{d}	3.97 ± 0.04^{d}	5.90 ± 0.01^{d}

TABLE 4. Content/activity levels of biochemical entities in *B. cucurbitae* larvae under the influence of coumarin (125 ppm)

Biochemical entities	Treatment	Content/activity (mean ± SE) Age of larvae and treatment duration			
		70 h[1] (0 h)[2]	94 h[2] (24 h)[2]	118 h[2] (48 h)[2]	142 h[2] (72 h)[2]
Total proteins	Control	18.49 ± 0.47	18.81 ± 0.18	20.78 ± 0.57	21.11 ± 0.50
(μg mg^{-1})	Coumarin	—	19.88 ± 0.31^{ns}	21.10 ± 0.23^{ns}	21.43 ± 0.07^{ns}
Esterases	Control	34.79 ± 1.29	37.58 ± 4.23	38.43 ± 3.67	51.88 ± 1.22
(μM mg^{-1})	Coumarin	—	38.55 ± 0.59^{ns}	50.55 ± 2.24^{a}	46.30 ± 0, 36^{b}
AcP	control	7.56 ± 0.01	13.32 ± 0.03	11.96 ± 0.18	9.24 ± 0.04
(μM mg^{-1})	courmarin	—	19.84 ± 0.10^{d}	16.56 ± 0.08^{ns}	14.88 ± 0.10^{d}
AkP	control	15.86 ± 0.09	12.42 ± 0.16	8.94 ± 0.08	12.60 ± 0.17
(μM mg^{-1})	Courmarin	—	4.20 ± 0.11^{d}	4.54 ± 0.01^{d}	4.48 ± 0.42^{d}
Glucose	Control	19.30 ± 0.47	18.46 ± 0.60	23.92 ± 0.60	25.29 ± 0.81
(μg mg^{-1})	Courmarin	—	22.95 ± 0.38^{a}	15.38 ± 1.19^{a}	18.33 ± 1.17^{a}
Glycogen	Control	6.46 ± 0.17	9.00 ± 0.12	10.26 ± 0.06	13.11 ± 0.46
(μg mg^{-1})	Coumarin	—	13.64 ± 0.31^{d}	11.26 ± 0.03^{c}	6.08 ± 0.19^{d}
Trehalose	Control	16.58 ± 0.51	24.30 ± 0.23	26.95 ± 0.20	35.22 ± 1.13
(μg mg^{-1})	Courmarin	—	20.96 ± 0.05^{c}	25.43 ± 0.04^{a}	31.55 ± 0.42^{ns}

($P < 0.001$), whereas it enhanced the activities of esterases as well as AcP (Table 4). This suggests interference of coumarin in the synthesis and storage of sugars which might be affecting the developmental duration, body weight and reproductive potential of adults, as has been observed in morphogenetic studies. Similar disturbances in the contents of sugars with coumarin treatment have been found in *L. erysimi* by Rup *et al.* (1998a). Corroboratory enhancing influence of abscisic acid (a natural abscissin) on the activities of esterases and AcP and the adverse effect on AkP have been reported in the case of *Z. paravittiger* (Rup and Kaur, 1993). Although protein content was not influenced with coumarin treatment in the present findings, low level of protein has been recorded in *L. erysimi* (Rup *et al.*, 1998a). Similarly, low protein concentration (vitellogenin) has been observed by De Man *et al.* (1981) in *Sarcophaga bullata* with abscisic acid treatment and this response was attributed to the similarity in the chemical configuration of ABA and JH. Similar inferences were drawn in grasshopper, *Aulocara elliotti* (Visscher, 1980).

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On a collection of Sphindidae (Coleoptera: Clavicornia) from Western Himalaya, India

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ABSTRACT: Two new sphindid species, *viz.*, *Aspidiphorus maheswar* and *A. uma*, of the four species recorded from Western Himalaya, are described. A key to the species of *Aspidiphorus* Latreille of the Indian subcontinent is appended.

KEYWORDS: Coleoptera, Sphindidae, *Aspidiphorus* Latreille, new species, Western Himalaya

INTRODUCTION

The Sphindidae is a sharply defined small family of Clavicornia (Polyphaga: Cucujoidea). The two large genera *Sphindus* Chevrolat and *Aspidiphorus* Latreille were earlier placed in two different families *viz.*, Sphindidae and Aspidiphoridae. Jacquelin du Val (1859–63) was first to treat them under a single family but Schenkling (1931) continued to follow the earlier treatment of placing them under two separate families. Crowson (1955) resurrected Jacquelin du Val's treatment but Horion (1961), and Freude *et al.* (1967) opined differently. Subsequently, Sengupta and Crowson (1977) redescribed and delimited the constitution of Sphindidae with a modified classification of the family. Sengupta and Pal (1982) while dealing with the Indian and Sri Lankan Sphindidae described 3 species of *Aspidiphorus*, totalling the Indian species of this genus to four. The present work is based on a collection of fungus-inhabiting beetles of this family provided by the Field Museum of Natural History, Chicago from Western Himalaya. It comprises three of the four species of *Aspidiphorus* Latreille recorded so far from this part, including two new species. The new species are named after a god and goddess of the Hindus, who are believed to reside in this mountainous part. A key to the species of *Aspidiphorus* of the Indian subcontinent is also provided.

Family: Sphindidae
Subfamily: Aspidiphorinae
Genus: Aspidiphorus Latreille

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1. Aspidiphorus dravida Sengupta and Pal

1982. *Aspidiphorus dravida* Sengupta and Pal, *Ent. Basel.* 7: 388 p.

Material examined: 8 ex. India: Himachal Pradesh, Summer Hill, 2000 m, 1 ex, 3.viii.1987, S. L. Stephenson, *ex. Dictydium cacnellatum*; same locality, 7 ex., 15.viii.1987, S. L. Stephenson, *ex. Stemonitis* sp. (2 ex.), *Dictydium cancellatum* (3 ex.), *Arcyria cineria* (2 ex.).

Distribution: India: Tamil Nadu, Himachal Pradesh (New record); Sri Lanka.

2. Aspidiphorus maheswar n. sp.

General appearance (Fig. 1) subglobular, slightly oblong, markedly convex; dorsal surface blackish brown; species covered with yellowish recumbent setae, moderately shiny.

Head broad, projecting downward, narrowed in front of eyes; eyes large, projecting and rounded, moderately coarsely facetted; fronto-clypeal suture rather angular, interocular distance about 0.55 x the width of head, interocular longitudinal grooves on vertex almost parallel posteriorly, additional longitudinal groove arises almost from base of longitudinal groove and runs transversely below eye, anterior margin of clypeus somewhat rounded; frons and vertex with minute setigerous punctures; punctures on clypeus finer, setae projected anteriorly. Antenna rather short, scape large, elongated and curved, pedicel short and narrow; segment 3 distinctly elongated and narrower than pedicel; segments 4–7 short, subequal and altogether slightly longer than segment 3; segment 8 about as broad as long, segment 9 transverse and segment 10 slightly elongated; scape to segment 7 reddish brown and club deep brown.

Prothorax distinctly transverse (1.0 : 1.8); front widely emarginate, front angles broadly pointed; lateral margin feebly rounded, posterior angles bluntly obtuse, basal margin forms an irregular arch and distinctly sinuates on either side of scutellum, sides of pronotum slightly explanate and finely bordered; puncturation on pronotum fine, moderately dense with interspaces wide on medial part, punctures denser with narrower interspaces towards sides; setae projected anteriorly.

Scutellum transversely triangular with apex broadly pointed, not setose.

Elytra broader at base than prothorax, basal margin emarginate fitting closely with prothorax, strongly convex, widest near middle, sides nearly straight with feeble sinuation; presence of a strong and broad protuberance between interstices 7 and 9 near humeral angle; a shallow, oblong depression between interstices 2 and 4 on anterior third of each elytron [sometimes depressions absent]; puncturation coarse and arranged in rows, space between successive punctures slightly narrower than punctures; setae projected posteriorly.

On ventral side from prosternum to first abdominal ventrite coarsely punctate.

Aedeagus (Fig. 3) bifurcate anteriorly with tips spatulate, arms distinctly elongate; dorsal part of tegminal ring acuminate apically (posterior end) with short-narrow process, ventral part of ring also narrow acuminate apically.

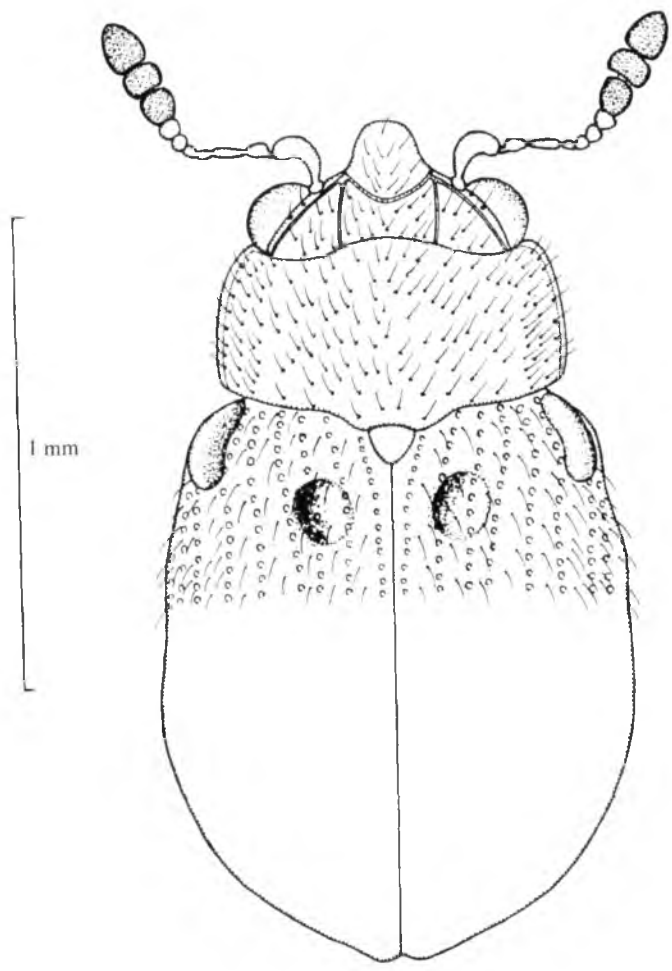

FIGURE 1. *Aspidiphorus maheshwar* n. sp., Dorsal view.

Measurements of holotype: Total length 1.54 mm; width of head across eyes 0.50 mm, length of antenna 0.42 mm, length and width of prothorax 0.36 and 0.64 mm, length and width of elytra 1.02 and 0.92 mm.

Holotype ♂, India: Himachal Pradesh, Narkanda, 2700 m., 19.vii.1967, S. L. Stephenson, *ex. Entyridium lycoperdon*. *Allotype* ♀, data same as holotype. *Paratypes* 41 ex. 16 ex, data same as holotype; 1 ex, same locality, 29.viii. 1967, S. L. Stephenson, 1 ex *Arcyria cinerea*; 2 ex, other data same as before, *ex. Stemonitis* sp., 1 ex, other data same as before, *ex. Lycogala exigum*; 1 ex, Manali in Kulu Valley, 2750 m, 11.ix.1987, S. L. Stephenson, 1 ex *Lamproderma arcyrionema*; 2 ex, other data same as before, 1 ex *Stemonitis* sp., 2 ex, Narkanda, 2700 m, 18.ix.1987,

S. L. Stephenson, 1 ex *Stemonitis flavogenita*; 4 ex, other data same as before, 1 ex *Stemonitis fusca*; 2 ex, other data same as before, 1 ex *Cribraria* sp.; 2 ex, other data same as before, 1 ex *Lycogala epidendrum. Holotype, Allotype* and 21 examples of *Paratypes* in Field Museum of Natural History, Chicago, and 21 examples of *Paratypes* in Zoological Survey of India, Calcutta.

Additional material: 19 ex. India: Himachal Pradesh, Narkanda, 2700 m; 1 ex, 19.vii.1987, S. L. Stephenson, 1 ex *?Symphytocarpus* sp; same locality, 14 ex, 29.vii.1987, S. L. Stephenson, *Stemonitis* sp. (1 ex), *Arcyria incarnata* (9 ex), *Lycogala exigum* (3 ex), *Tubifera ferruginosa* (1 ex); same locality, 4 ex, 18.iv.1987, S. L. Stephenson, *ex. Enerthenema papillatum* (1 ex), *Cribraria* sp. (2 ex), *Comatricha typhoides* (1 ex).

Remarks: This species shows close similarity with *A. bhuswargabasi* Sengupta and Pal [described from Kashmir] from which it can be distinguished by the following characters; aedeagal apex (posterior tip) is placed far from ventral apex of tegminal ring, ventral part of tegminal ring gradually narrowed apically and distinctly elongated. Several examples cited under *Additional material* show the variation from typical *maheshwar* by the absence of shallow paired depressions on anterior half of elytra. The aedeagal structures in *Aspidiphorus* seemed to be species-specific. These additional examples having external variations perhaps belong to a separate species despite similar aedeagal features. But for more affirmative characters from more material these examples are presently treated under *maheshwar*.

3. Aspidiphorus uma n. sp.

General appearance (Fig. 2) subglobular, slightly oblong, markedly convex; dorsal surface blackish brown; antennae and legs reddish brown, club darker; species covered with yellowish recumbent setae, moderately shiny.

Head broad projecting downward, narrowed in front of eyes; eyes large, projecting and rounded, moderately coarsely facetted; fronto-clypeal suture rather angular, interocular distance about 0.55 x the width of head, interocular longitudinal grooves on vertex diverging posteriorly, additional longitudinal grooves arises from each longitudinal groove and runs transversely below eye, anterior margin of clypeus broad; frons and vertex impunctate, shiny, setae projected anteriorly. Antenna rather short, scape large, elongated and curved; pedicel short and narrow; segment 3 distinctly elongated and narrower than pedicel; segments 4–7 short, subequal and altogether slightly longer than segment 3; segments 8 and 10 slightly elongated, segment 9 about as broad as long; scape to segment 7 reddish brown and club deep brown.

Prothorax distinctly transverse (1.0 : 1.8); front widely emarginate, front angles broadly pointed, lateral margins feebly rounded, posterior angles bluntly obtuse, basal margin forms an irregular arch and distinctly sinuates on either side of scutellum, sides of pronotum slightly explanate and finely bordered; puncturation on pronotum fine, moderately dense, irregular, considerable space on the disc impunctate as seen in figure; setae projected anteriorly.

Scutellum heart-shaped, apex broadly pointed, devoid of setae.

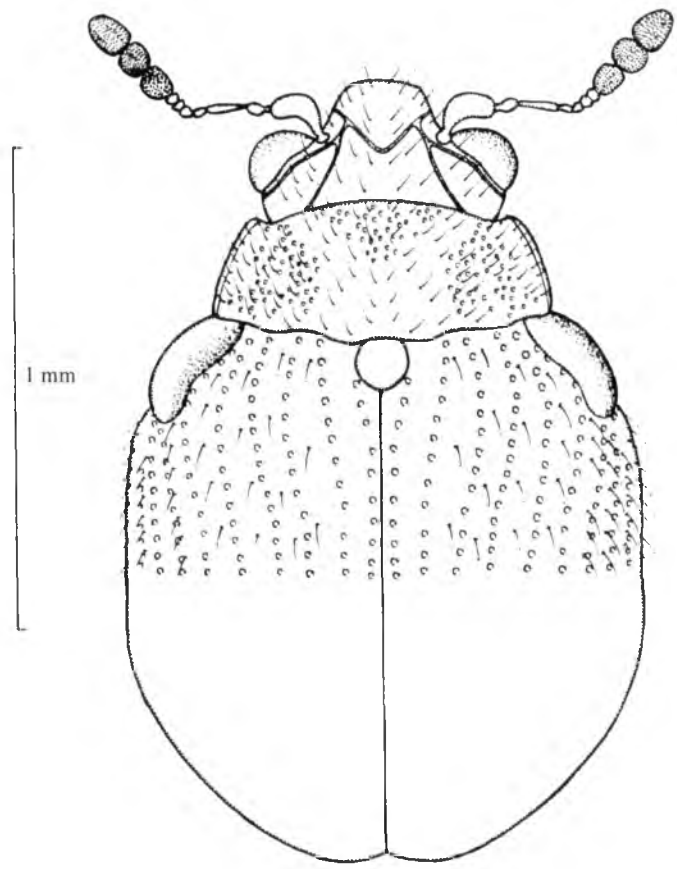

FIGURE 2. *Aspidiphorus uma* n. sp., Dorsal view.

Elytra broader at base than prothorax, basal margin emarginate fitting closely with prothorax, strongly convex, widest near middle, sides nearly straight with feeble sinuation; presence of a strong and broad protuberance between interstices 7 and 9 near humeal angle; puncturation coarse and arranged in rows; space between successive punctures more or less as wide as punctures; setae projected posteriorly.

On ventral side from prosternum to first abdominal ventrite coarsely punctate.

Aedeagus (Fig. 4) bifurcate anteriorly with tips spatulate, arms short; dorsal part of tegminal ring acuminate apically (posterior end) with long narrow process, ventral part of ring broadly rounded apically.

Measurements of holotype: Total length 1.68 mm, width of head across eyes 0.52 mm, length of antenna 0.52 mm, length and width of prothorax 0.48 and 0.76 mm, length and width of elytra 1.20 and 1.10 mm.

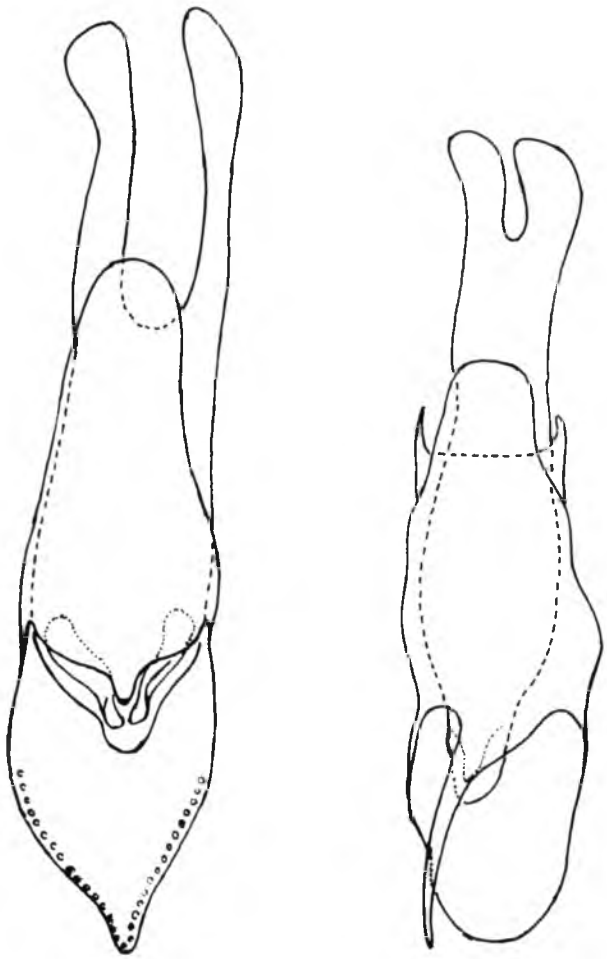

FIGURE3–4: Aedeagi, Dorsal view. 3, *Aspidiphorus mahehwar*, n. sp., 4 *Aspidiphorus uma* n. sp.

Holotype ♂, India: Himachal Pradesh, Narkanda, 2700 m, 18.ix.1987, S. L. Stephenson, ex *Cribraria* sp. *Allotype* ♀, same locality, 19.vii.1987, S. L. Stephenson, ex *Entiridium lycoperdon. Paratypes*: 23 ex. data same as allotype; 17 ex, same locality, 29.viii.1987, S. L. Stephenson, 1 ex *Arcyria incarnata*; 1 ex, same locality, 18.ix.1987, S. L. Stephenson, 1 ex *Lycogala epidendrum*; 1 ex, other data same as before, 1 ex *Stemonitis fusca. Holotype, Allotype* and 11 examples of *Paratypes* in the Field Museum of Natural History, Chicago and 12 examples of *Paratypes* in Zoological Survey of India, Calcutta.

Remarks: This species resembles *A. bhuswargabasi* Sengupta and Pal and *A. maheshwar* n. sp. in facies but can be distinguished by the puncturation on pronotal disc irregular and not uniformly distributed; bifurcate anterior arms of aedeagus short, base of tegminal cap (anteriorly) not extending up to level of bifurcation of aedeagal arms, ventral part of tegminal ring broadly rounded apically.

Key to the species of *Aspidiphorus* Latreille of the Indian subcontinent

1. Antennal segment 4 distinctly elongated and about as long as segments 5–7 together ..... *asiaticus* Champion

- Antennal segment 4 short and distinctly shorter than segments 5–7 together 2

2. Sides of elytra uniformly curved, rounded and not sinuate. .... *dravida* Sengupta and Pal

– Sides of elytra nearly straight with sinuation 3

3. Antennal segments 8 and 9 elongated..... *bhutia* Sengupta and Pal

– Antennal segments 8 and 9 about as broad as long or slightly transverse 4

4. Puncturation not uniformly distributed on pronotal disc, considerable space on disc impunctate (Figure 2). Bifurcate arms of aedeagus short, base of tegminal cap (anteriorly) not extending up to level of bifurcation of aedeagal arms, ventral part of tegminal ring rounded apically (posteriorly) ..... *uma* n. sp.

– Punctures uniformly distributed throughout over pronotal disc. Bifurcate arms of aedeagus long, base of tegminal cap (anteriorly) extending beyond level of bifurcation of aedeagal arms, ventral part of tegminal ring acuminate apically (posteriorly) 5

5. Aedeagal apex (posterior) placed close to dorsal apex of tegminal ring and far from ventral apex (Figure 3) ..... *maheshwar* n. sp.

– Aedeagal apex placed close to ventral apex of tegminal ring .... *bhuswargabasi* Sengupata and Pal

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Impact of forest fire on insect species diversity—A study in the Silent Valley National Park, Kerala, India

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ABSTRACT: The impact of forest fire on insect species diversity was studied in representative plots in the Silent Valley National Park in the Kerala part of Western Ghats. The plots were laid out in such a way that forest patches representing both disturbed and undisturbed areas were covered. Shannon-Weiner diversity indices for insects and plants were determined separately for disturbed and undisturbed ares. The fire affected areas showed reduction in species diversity both in flora and fauna. The similarity index calculated for the various sites indicated that there was considerable difference between the sites and that each area was specialised with respect to its faunal elements. The undisturbed areas had good representation of primary plant species such as *Palaquium ellipticum*, *Myristica dactyloides* and *Vateria indica* whereas, in the disturbed area, there was a reduction in the number of primary species and invasion by secondary species like *Macaranga peltata*, *Zizyphus rugosa* and *Celtis* sp. and weeds such as *Lantana camara*, *Chromolaena odorata* and *Clerodendrum viscosum*. With regard to insects, the disturbed areas had more of herbaceous feeding forms belonging to the families, Noctuidae, Pyralidae, Chrysomelidae etc. whereas the undisturbed areas were rich in arboreal feeding insects belonging to the families, Cossidae, Geometridae and Saturnidae. The impact of disturbance on biodiversity was evident from the diversity values as well as the floral and faunal elements of the disturbed and undisturbed areas. Altogether, 578 species of insects belonging to 13 orders were collected, of which 275 species have been identified. Maximum number of species collected belonged to the Orders Lepidoptera and Coleoptera. The most dominant families were Pyralidae, Noctuidae and Geometridae (Lepidoptera) and Chrysomelidae, Cerambycidae and Tenebrionidae (Coleoptera). Based on the 'collector's curve' and 'distribution model', the study revealed that the area contained more species than could be collected in the present investigation indicating the need for further studies.

KEYWORDS: Forest insect diversity, effect of fire, Silent Valley

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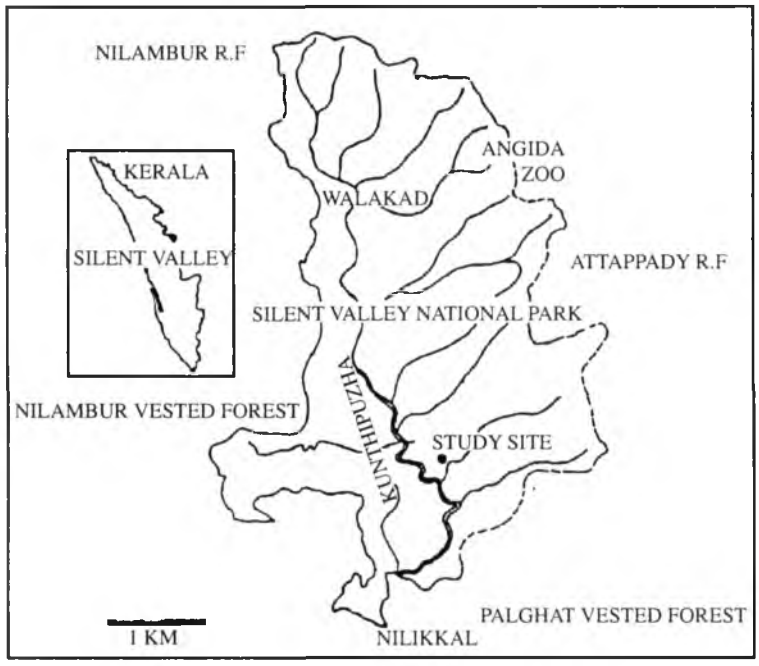

FIGURE 1. Map of Silent Valley National Park showing the study site.

INTRODUCTION

The Silent Valley National Park, one of the core zones of the Nilgiri Biosphere Reserve, is situated in the Palghat District of Kerala, between latitudes 11 °3′ and 11 °15′ N and longitudes 76 °23′ and 76 °30′ E (Fig. 1). The area, which was declared as a National Park in 1984, falls under the Malabar Rainforest Realm (Udvardy, 1975). Covering an area of about 90 km^2, this Reserve is situated more or less on a plateau at about 1000 m elevation. The Nilambur Forest Division and parts of Nilgiris in the north, the Vested Forest of Palghat and Nilambur in the south and the west and the Attappady Reserve Forests in the east, form its boundaries. The river Kunthipuzha that is a tributary of Bharathapuzha, takes its origin among the hillocks in this region. Heavy summer rains characterize this region. The mean annual rainfall is about 4400 mm spread over both southwest and northeast monsoons. The mean annual temperature is 20 °C. April and May are the hottest months of the year when the mean temperature goes up to 23.5 °C. December, January and February are the coolest months when the mean temperature is around 18 °C. From June to December the relative humidity is consistently high and is often around 95%.

Accessibility to this area is restricted due to the steep slopes on all sides and this has contributed to the area remaining more or less undisturbed. The adjacent Attappady Reserve, which lies to the east of Silent Valley, is more accessible and has suffered severe disturbance in its eastern portion. The forests of Silent Valley exhibit considerable variations in floristic composition, physiognomy and life forms

due to climatic, edaphic and altitudinal variations (KFRI, 1990). The types of forests recognized are west-coast tropical evergreen forest, subtropical broad-leaved hill forests, montane wet temperate forests and grasslands—low and high level.

The present study was carried out in a wet evergreen forest patch (Fig. 1). This type of forest is commonly encountered between 600 to 1100 m. The trees are about 45 m high and at least three strata of vegetation can be recognized. The trees of the top canopy have a spreading of umbrella-shaped crown. The middle stratum is candle-shaped and the lower is characteristically conical. *Artocarpus heterophyllus*, *Calophyllum elatum*, *Canarium strictum*, *Cullenia exarillata*, *Dysoxylum malabaricum*, *Elaeocarpus tuberculatus*, *Holigarna spp.*, *Mesua ferrea*, *Palaquium ellipticum*, *Persea macrantha* and *Poeciloneuron ellipticum* are the common tree species found in this forest.

The major disturbance is due to fire, which frequently occurs during the summer season in the grasslands and spreads to the adjacent natural forests. Although the grasslands contain fire hardly species, which may sprout with the rains, fire in the evergreen forests will affect the delicate ecosystem characteristic of such habitats leading to the disappearance of many evergreen species. The gaps formed in the forest due to burning subsequently get colonised by various secondary species that are found in the adjacent moist deciduous forests and grasslands.

MATERIALS AND METHODS

The study was carried out in representative plots selected in the disturbed (fire affected) and undisturbed forest patches. Eight plots were laid out at fixed intervals along a transect in such as way that four plots are in the disturbed zone and the remaining in the undisturbed zone. The plot size was fixed at 625 m^2 and the distance between plots was 25 m. Data on vegetation and insects were collected from all the eight plots in each locality and from this, the indices of diversity, dominance, evenness, species richness etc. of plants and insects were computed separately for the disturbed areas were pooled for deriving the overall values for each locality. Details of methodology followed for studies on vegetation and insect community are described below.

Sampling methods

Vegetation was studied with a view to generate base line data on the floral elements in order to understand the relationship between the vegetation and insect community. Plants above 2 cm diameter were enumerated in all the study plots. The diameter of small plants was measured at about 6 cm from ground. In the case of tall plants, girth at breast-height (gbh) was recorded. Based on girth, the tall plants were classified into different categories *viz.*, mature trees (individuals with gbh more than 30 cm), saplings (individuals with gbh <10.1–30 cm), seedlings, shrubs, herbs and climbers (individuals with girth <10 cm) (Chandrashekara and Ramakrishnan, 1994).

Sampling of insects was done using a battery operated light trap specially fitted with a switching device to facilitate self operation at specified hours (Mathew, 1996).

In order to avoid the influence of lunar phase on insect catches, the trap was operated alternately between plots in the disturbed and undisturbed areas i.e. if the trap was operated initially in plot 1 in the disturbed area, on the next day, it was operated in plot 1 of the undisturbed area and then in plot 2 of the disturbed area and so on. In addition to trap catches, collections were also made during daytime (8 am to 1 pm) using hand nets. At each location, collections were made for a period of one year. The insects collected were sorted out to species and the number of individuals for each species was recorded on data sheets. As it was not possible to identify all the species readily, code numbers were assigned to the various species. The insects were later identified by comparison with national collections at IARI, New Delhi and ZSI, Calcutta.

Analysis of data

Density: Density was estimated for various plant categories such as trees, saplings, seedlings, shrubs, herbs and climbers in each locality for disturbed and undisturbed sites and the pooled values were also calculated separately.

Diversity index: Shannon–Weiner diversity index was calculated as given in Margalef (1968). In order to find out whether any significant difference existed in the insect diversity of the disturbed and undisturbed areas, a '*t*' test was done (Magurran, 1988).

Distribution models: This is another way of describing diversity in a community (Fisher *et al.*, 1943). A species-abundance model utilises all the information gathered in a community and is the most complete mathematical description of the data (Magurran, 1988). The frequency distribution of insects per collected species was studied and the data were described using truncated log-normal distribution (Pielou, 1975), which will indicate whether the locality contain any rare species or not and also, the number of species which had not been possibly included in the sample collection.

Similarity measures: The similarity between disturbed and undistrubed areas was studied by calculating the modified Sorensen's coefficient of similarity.

Dominance index: The dominance index was calculated for studying the patterns of relative abundance of each insect Order in the study site. The following formula was used:

Dominance index $= n_i \times 100/N$, where n_i = number of insects in the ith order, and N = the total number of insects in all the orders collected during the study period.

Evenness or equitability index: This index, which measures the evenness of species abundance is complimentary to the diversity index concept and it indicates how the individuals of various species are distributed in the community. For estimating evenness, Shannon's evenness index was calculated (Pielou, 1975, 1977).

TABLE 1. Characteristic of the vegetation in the undisturbed and disturbed[1] sites at Silent Valley

Community parameters	Category	Plant categories						
		Mature trees	Tree saplings	Tree seedlings	Shrubs	Herbs	Climbers	Total
No. of species	UD	35	48	46	9	4	9	81
	D	33	48	50	18	11	16	109
No. of individuals	UD	191	488	575	262	44	48	1608
	D	116	493	668	711	208	147	2343
Diversity	UD	2.99	3.22	3.29	1.67	1.15	1.84	3.66
	D	2.93	2.54	3.04	1.93	1.32	2.19	3.55
Richness	UD	2.53	2.17	1.92	0.56	0.60	1.30	2.02
	D	3.06	2.16	1.93	0.68	0.76	1.32	2.25
Evenness	UD	0.84	0.83	0.86	0.76	0.83	0.84	0.83
	D	0.84	0.66	0.78	0.67	0.55	0.79	0.76

UD: Undisturbed; D: Disturbed; Plot size: 25 × 25 m; Replicates: 4 plots per habitat

Species richness: In the ecological literature, the number of species at a site, in a region or in a collection is called species richness, which is the simplest and most useful measure of species diversity. In this study, the total number of insect species collected in each month from each locality was considered as species richness.

Species richness index: The index of species richness was calculated using the formula given by Menhinick (1964).

RESULTS

Vegetation studies

In the undisturbed area, out of 81 plant species recorded, 48 were represented as saplings, 46 as seedlings and 35 as mature trees (Table 1). Herbs, shrubs and climbers were sparse. *Palaquium ellipticum, Aglaia* sp., *Myristica dactyloides, Mesua ferrea, Cullenia exarillata, Dimocarpus longan, Drypetes oblongifolia, Holigarna arnottiana, Casearia bourdilonii, Garcinia morella, Litsea floribunda, Persea macrantha, Syzygium cumini* and *Artocarpus heterophyllus* were the common tree species in this area. Tree seedlings showed higher species diversity followed by tree saplings, mature trees, climbers, shrubs and herbs (Table 1). With regard to density, highest values obtained were for tree seedlings (575) followed by tree saplings (488). The index of species richness was higher for mature trees (2.53) followed by tree saplings (2.17). Evenness index was found to be higher for tree seedlings.

In the disturbed area, out of 109 species recorded, 33 were present as mature trees, 48 as tree saplings and 50 as tree seedlings (Table 1). Shrubs, herbs and climbers were sparse. The tree diversity was lower than in the undisturbed are although species such as *Cullenia exarillata, Dimocarpus longan* and *Casearia bourdilloni*, were present. In addition to these, secondary species like *Olea dioica, Scolopia crenata, Clerodendrum*

TABLE 2. No. of species collected from Silent Valley National Park in different months

Category	No. of species collected												
	1995							1996					
	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total
Undisturbed area	42	48	112	136	125	94	37	155	88	38	161	218	449
Disturbed area	52	74	91	131	56	73	34	122	68	66	166	207	417

Plot size: 25 × 25 m; Replicates: 4 plots per habitat.

viscosum, *Macaranga peltata* and *Zizyphus rugosa* were also present. Tree seedlings showed higher species diversity compared to all other categories. Species diversity values were low for herbs and shrubs. Highest density obtained was for shrubs followed by seedlings. The index of species richness was found to be higher for mature trees followed by tree saplings. Evenness index was also found to be higher for mature trees.

Insect community

Altogether 578 species belonging to 13 orders and 67 families were collected. Of these, 449 species were from the undisturbed and 417 species from the disturbed areas. In the former, the insects collected belonged to 13 orders and 61 families and in the latter to 12 orders and 60 families. The number of species collected from the disturbed and undisturbed areas in each month are shown in Table 2.

Species richness

In both the areas, maximum collection was during May and least in December. During June–July 1995, there was a slight reduction in the catches from the undisturbed area, compared to the disturbed area. Significant difference was found in the number of species collected in various months from the undisturbed ($\chi^2 = 347.89$) and disturbed areas ($\chi^2 = 307.47$).

Species richness index

The values for the undisturbed and disturbed areas were 5.91 and 6.10, respectively. The index was found to be high for the disturbed area, which indicates that the total number of individuals and species occurring in this area is high. This increase in species richness in the disturbed area could be due to two reasons: (1) the disturbance was mild, confined to relatively smaller patches and of recent origin and (2) the colonisation of the disturbed patches might have provided more habitats leading to diversified insect communities.

Dominance index

The dominance index for insects collected from Silent Valley is given in Table 3.

TABLE 3. Dominance indices for insect groups at Silent Valley.

Order	Percentage of species		Dominance index	
	Undisturbed	Disturbed	Undisturbed	Disturbed
Coleoptera	22.27	24.22	14.75	16.13
Dermaptera	0.45	0.24	0.64	0.54
Dictyoptera	1.11	1.44	1.31	0.73
Diptera	9.13	8.39	30.84	32.87
Ephemeroptera	0.45	0.48	0.09	0.19
Isoptera	0.45	0.96	0.99	3.66
Hemiptera	7.79	9.84	6.08	3.61
Hymenoptera	3.56	3.8	15.01	12.90
Lepidoptera	49.67	46.28	25.25	23.59
Mecoptera	0.22	0.24	0.02	0.02
Neuroptera	0.22	—	—	0.04
Orthoptera	0.89	0.96	0.51	0.34
Trichoptera	3.79	3.12	4.52	5.39

TABLE 4. Monthly collection of insects from the study areas in Silent Valley

Category	1995							1996					Total
	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	
Undisturbed area	73	152	406	923	428	314	73	760	269	109	877	1398	5781
Disturbed area	102	230	326	472	149	167	63	467	175	215	1057	1248	4670

The dominant insect orders with respect to number of species, in both the areas at Silent Valley were Diptera and Lepidoptera followed by Coleoptera and Hymenoptera. The dominance indices were more or less similar for both localities (disturbed and undisturbed) and showed only slight differences. Maximum number of species collected belonged to Lepidoptera in both the undisturbed (49.67%) and the disturbed areas (46.28%) followed by Coleoptera (22.27% in the undisturbed and 24.2% in the disturbed areas) (Table 3).

Species abundance

The number of insects collected during the various months ranged from 73 to 1398 in the disturbed area and from 63 to 1248 in the disturbed area. The number of individuals collected was less during June and December 1995 and high in April–May 1996 in the undisturbed area (Table 4).

The Chi-squre test showed significant difference in the number of insects in various months for the undisturbed ($\chi^2 = 4009.78$) and disturbed ($\chi^2 = 4105.99$) areas.

TABLE 5. Species diversity indices recorded for insects at Silent Valley

	Shannon's index of diversity												
	1995							1996					
Area	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Pooled
Undisturbed area	3.51	3.48	4.08	3.41	4.26	3.98	3.35	4.03	3.89	3.13	4.11	4.15	4.76
Disturbed area	3.50	3.68	3.83	4.22	3.46	3.71	3.34	3.80	3.58	3.52	4.11	3.92	4.65

Species diversity

Even though species abundance model provides full description of diversity, it cannot be used for comparison of diversity. For this, the Shannon's index of diversity was calculated which is a measure of diversity. Monthly variations in Shannon's index of diversity in the undisturbed and disturbed areas are presented in Table 5.

The diversity index remained more or less in the same range throughout the period of study although there was a slight reduction in the undisturbed area during December 1995 and March 1996. In the disturbed area, diversity was low in December 1995. A t-test was done to determine the significant difference between the disturbed and undisturbed areas in terms of species diversity. The t-value was found to be highly significant (2.29), which shows that the species present in the undisturbed area is more diverse than those in the disturbed area.

Distribution model

The observed and expected number of species at Silent Valley was compared using χ^2 goodness of fit test. The test showed no significant difference between the observed and expected distribution ($\chi^2 = 11.47$), which indicates that the distribution pattern of species is following truncated log-normal distribution. While the log-normal distribution is a symmetrical 'normal' bell-shaped curve, in the case of truncated log-normal distribution, the left hand portion of the curve called veil line (representing the rare/unsampled species) will be obscured (Magurran, 1988). The number of species which comes behind this line denotes the rare or unsampled species.

In the present study at Silent Valley, there were 202 species that belonging to this category (Table 6) which indicates the need for further sampling to arrive at a more realistic account of species occurring in this area.

Evenness or equitability indices

The evenness indices obtained for the undisturbed area was 0.78 and for the disturbed area it was 0.77 indicating that the undisturbed are contained more species and that they are uniformly distributed. The evenness index is complementary to the diversity index concept and it indicates how the individuals of various species are distributed in the community.

TABLE 6. Truncated log-normal distribution at Silent Valley

Classes	Upper class boundary	Observed species	Expected species	χ^2
Behind veil line	0.5	—	202.17	—
1	2.5	248	236.58	0.55
2	4.5	88	86.81	0.02
3	8.5	73	81.54	0.89
4	16.5	57	66.72	1.42
5	32.5	49	47.34	0.06
6	64.5	25	29.60	0.71
7	128.5	25	16.18	4.81
8	256.5	5	7.89	1.06
9	512.5	6	3.42	1.95
10		2	1.92	0.003
Total		578	780.17	11.47

Similarity measures

Similarity index was calculated using modified Sorenson's formula and the value obtained was 0.65. It indicates that there is 65% similarity between the undisturbed and disturbed areas.

DISCUSSION

The patterns of species diversity showed interesting trends with the fire affected areas showing differences in the floral and faunal elements besides reduction in diversity. The disturbed area in Silent Valley contained 2343 plants belonging to 109 species compared to 1608 plants belonging to 81 species in the undisturbed area. The undisturbed areas had good representation of primary plant species such as *Palaquium ellipticum*, *Myristica dactyloides* and *Vateria indica* whereas, in the disturbed area, there was a reduction in the number of primary species and invasion by secondary species like *Macaranga peltata*, *Zizyphus rugosa* and *Celtis* sp. and weeds such as *Lantana camara*, *Chromolaena odorata* and *Clerodendrum* sp. With regard to the occurrence of various plant categories, the disturbed area had more of shrubs, herbs, climbers, tree seedlings and saplings indicating good colonisation. The plant diversity index for the undisturbed area was 3.66 and for the disturbed area, it was 3.55.

With regard to the insects, 5781 individuals belonging to 449 species were recorded from the undisturbed area and 4670 insects belonging to 417 species from the disturbed area. The disturbed areas had more of herbaceous feeding forms belonging to the families, Noctuidae, Pyralidae, Chrysomelidae etc. whereas the undisturbed areas were rich in arboreal feeding insects belonging to the families, Cossidae, Geometridae and Saturnidae. The insect diversity index of the undisturbed area was high (4.76) compared to the disturbed area (4.65). The impact of disturbance on biodiversity was

evident from the diversity values was well as the floral and faunal elements of the disturbed and undisturbed areas. Similar trend was observed at other locations such as Sholayar, Nelliyampathy and Parambikulam (Mathew *et al.*, 1998). The similarity index calculated for the various sites indicated that there was considerable difference between the sites and that each area was specialised with respect to its faunal elements. Altogether, 578 species of insects belonging to 13 Orders were collected, of which 275 species have been identified. Isolation of forest habitats at Silent Valley and relatively low exposure to forest disturbance on account of greater protection might have lead to greater stability to the forest ecosystem in the area leading to greater diversity of the disturbed habitats. Based on the 'collector's curve' and 'distribution model' (log-normal distribution), the study has also shown that the area contains more species than could be collected in the present investigation indicating the need for further studies.

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Systematic studies on *Diastephanus* Enderlein (Hymenoptera: Stephanoidea: Stephanidae) of Indian subcontinent

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ABSTRACT: Seven new species of *Diastephanus viz.*, *Diastephanus priyae*, *Diastephanus sudhae*, *Diastephanus keralensis*, *Diastephanus anupam*, *Diastephanus daccaensis*, *Diastephanus stom* and *Diastephanus burmaensis* are described. A key to species of *Diastephanus* of Indian subcontinent is provided.

INTRODUCTION

Most species of Stephanidae are believed to be parasitic on large wood-boring beetles. Very little is known on the Indian Stephanidae. The family consists of 9 genera and about 100 species (Mason, 1993). The genus *Diastephanus* was erected by Enderlein (1905). It comes very near the genus *Foenotopus* Smith but differs in venation. It seems likely that these two genera will be eventually united when intermediate species are known. So far only 4 species are known under the genus *Diastephanus* from Indian subcontinent. They are *D. frontilinea* Morley (from Bangaladesh and Assam), *D. bilineatus* Elliott (from Bihar), *D. wayanadensis* Sureshan and Narendran (from Kerala) and *D. chinnarensis* Suresh (from Kerala) (Elliott, 1922; Sureshan and Narendran, 1997; Sureshan, 1997). In this paper, 7 new species are described and diagnosis of the 4 known species are given. A key for identification of Indian species is provided.

Abbreviation used: POL = Post ocellar line; OOL = Ocellocular line; BMNH = British Museum Natural History, London; ZSIC = Zoological Survey of India, Western Ghat Regional Station, Calicut; IARI = Indian Agricultural Research Institute, New Delhi.

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***Diastephanus priyae* sp. nov. (Figs. 1–3)**

Female

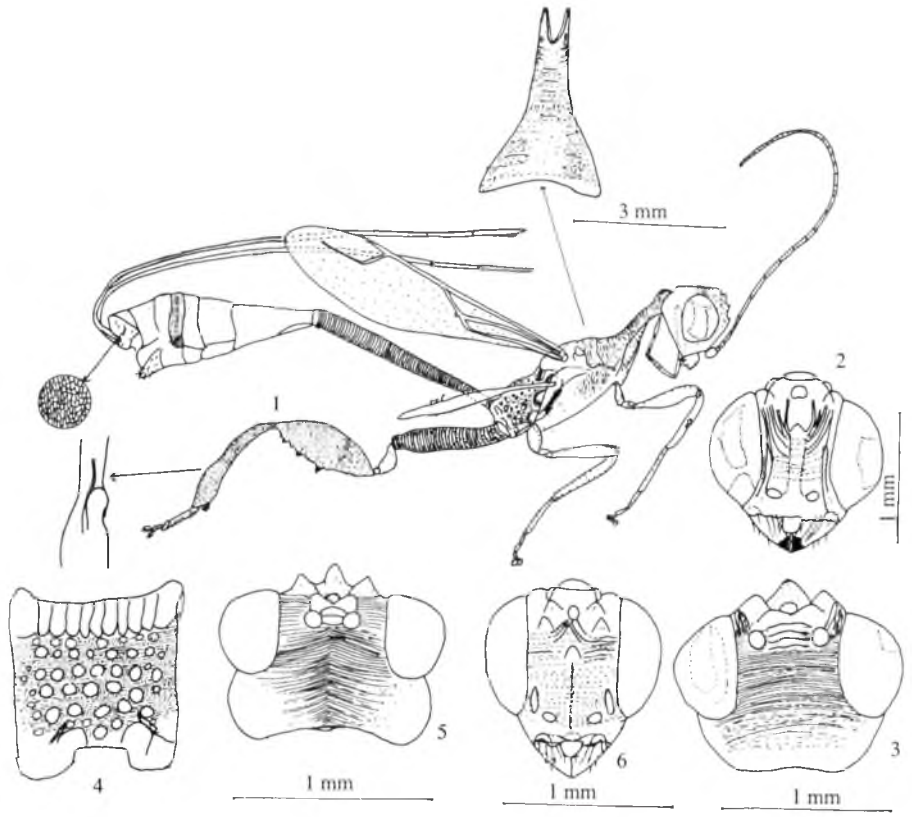
Length = 12.37 mm (excluding terebra); terebra = 8.77 mm. Black with following parts as follows: frons below anterior tooth with three longitudinal yellow bands, median band touching base of front tooth; lateral bands closely adjacent to anterior eye margin, lower ends of bands confluent; clypeus and labrum yellow; mandibles yellowish brown with apices black; gena and lower part of region behind eyes pale brown with a pale yellow band adjacent to posterior lower margin of eye; maxillary palp and labial palp brown with basal segments paler; eyes black with paler patches; ocelli reflecting blackish brown; anteena dark brown with pedicel, scape and radicle pale brown. Fore leg black with bases of trochanter and femur brown; fore tibia black with a pale yellow longitudinal strip from base to apex and this band broken on the swollen subbasal part with intervening black colour; tarsi brown; fifth tarsal segment darker. Mid leg similar to fore leg in colour except that dorsal yellow band not broken by black and metatarsus whitish yellow. Hind leg black with metatarsus pale brown and last tarsal segment brownish black. Metasoma black with first and second post petiolar segments yellowish brown on sides; hypopygium brown at apex; terebra brownish black with subapical yellow band. Wings hyaline with veins brown; stigma translucent yellow in middle; pubescence silvery.

Head

(Figs 2 and 3) width in anterior view a little more than 1.28× distance between front ocellus and lower margin of labrum; head width in dorsal view 1.5× distance between front ocellus and occipital margin; frons trans-striate with longitudinal and oblique striae below middle pair of teeth (Fig. 2); ocellocular area obliquely striate; vertex with four transverse carinae followed by fine striae (Fig. 3), striae not forming a median line; posterior margin of head sharply bordered; gena and postorbital region smooth and shiny. POL 4× OOL; head with 5 teeth, anterior one stronger and separated from next pair by a little more than 1.4× distance between each other. Antenna with scape 1.25× as long as pedicel; first flagellar segment 1.5× as long as pedicel; second flagellar segment 1.5× as long as first; third a little longer than second; fourth slightly longer than third; fifth slightly shorter than fourth.

Mesosoma

With neck trans-striate weakly on dorsal side, finely reticulate on lateral and ventral sides. Mesoscutum faintly reticulate, shiny on anterior half, with large shallow pits with interstices faintly reticulate (visible only under certain reflection of lights, otherwise looks smooth and shiny). Scutellum and axilla almost smooth and shiny with a few scattered pits on sides of scutellum; axilla separated from scutellum by oblique row of deep pits; axillae separated from each other by a large pit in front of scutellum. Metanotum with a transverse row of deep pits separated by longitudinal carinae. Mesopleuron shagreened and with a few scattered pits with dense short silvery



Figs 1–4: *D. priyae* sp. nov. (Female): 1. Body profile; 2. Head anterior view; 3. Head dorsal view; 4. Propodeum dorsal view. Figs 5–6: *D. wayanadensis* Sur. & Narendran (Female) 5. Head dorsal view; 6. Head anterior view.

pubescence on anterior half. Metapleuron rugosoreticulate. Propodeum with broad deep pits, iterstices shagreened and lesser than half diameter of each pit in most places; length of propodeum a little more than 0.26× length of petiole. Relative median lengths of pronotum: 23; mesoscutum: 5; scutellum: 11, metanotum: 2.5; propodeum: 15. Forewing length a little more than 4.38× as long as its maximum width. Fore femur basally petiolate; proximal half of hind coxa reticulate and transversely striate, distal half transversely striate alone; hind femur finely reticulate, with 3 large teeth on ventral margin with several minute dentation inbetween; two small tubercles present anterior to basal large tooth; length of hind femur subequal to hind coxa; hind tibia finely reticulate and clavate apically.

Metasoma

smooth petiole uniformly trascarinate; petiole almost as long as combined length of post petiolar segments (excluding terebra). Length of first postpetiolar tergite a little

shorter than 2× second postpetiolar tergite (21 : 11); length of terebra 2.28× length of metasoma (excluding petiole), as long as 1.17× metasoma including petiole.

Male

Length 7–10 mm. Similar to female except in the following: frons below level of front tooth and face completely immaculate yellow; vertex with 3 carinae (rarely 4 carinae seen); petiole length 1.1 to 1.33× length of remaining part of metasoma.

Host

Unknown

Holotype

Female: India, Kerala, Thrissur, 12.vi.1999 Coll., Priya Menon (ZSIC).

Paratypes

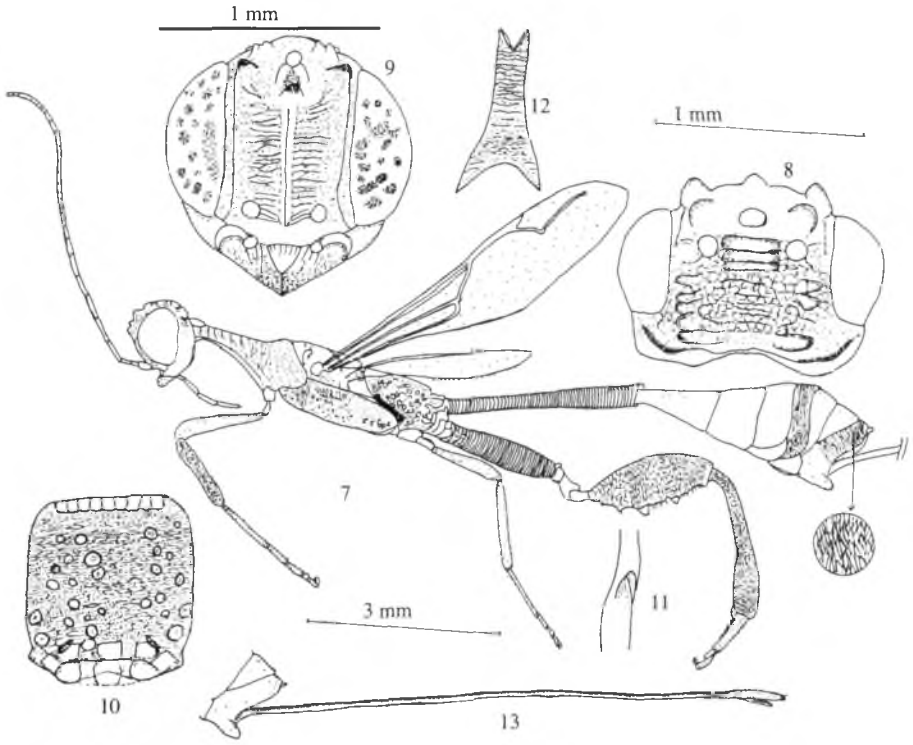
4 male of same data as for holotype except date 19.iv.1999.

Etymology

The species name is after the collector of the specimens.

DISCUSSION

In the key to species of *Diastephanus* (Elliott, 1922) this new species comes to couplet No.10 but differs from *Diastephanus bilineatus* Elliot in having: (1) terebra 2.28× as long as metasoma, (excluding petiole) (in *bilineatus* 1.4× as long as metasoma, excluding petiole); (2) all femoral teeth black (in *bilineatus* central femoral tooth white); (3) vertex with 4 carinae in female (in *bilineatus* vertex with 2 carinae in female); (4) third flagellar segment equal to combined length of first and second together (in *bilineatus* it is not so) and in several other features. This new species also comes to couplet No.13 but differs from *D. gracilis* Kieffer in having: (1) vertex in female with 4 transeverse carinae (in *gracilis* vertex with 5 carinae); (2) posterior margin of head bordered (in *gracilis* posterior margin of head simple and not distinctly bordered); (3) scutellum mostly smooth and shiny (in *gracilis* finely punctate on scutellum); (4) terebra with subapial yellow band (in *gracilis* terebra completely black) and (5) in having frons with yellow bands (in *gracilis* frons black). This new species differs from *D. wayanadensis* Sureshan and Narendran by the characters given in the key.



Figs 7–13: *D. sudhae* sp. nov. (Female): 7. Body profile; 8. Head dorsal view; 9. Head anterior view; 10. propodeum dorsal view; 11. Middle part of hind tibia inner view; 12. pronotum dorsal view; 13. Terebra.

***Diastephanus sudhae* sp. nov. (Figs 7–13)**

Female

Length 12.05 mm (excluding terebra); terebra length 8.8 mm, Black with following parts as follows: frons below frontal teeth reddish brown; basal 5 segments of antenna including radicula reddish brown; gena, postgena and temples brown; mandibles black with base paler; labrum and clypeus brown; basal segments of maxillary and labial palps brown; eyes with pale yellowish and blackish markings; ocelli reflecting reddish brown; ventral and basolateral sides of neck brown; fore tarsus pale brown; second, third and fourth mid tarsal segments pale brown; femur with central and distal large teeth pale whitish yellow; metatarsus of hind leg dark brown; terebra without yellowish or whitish bands. Wings hyaline with veins brown; stigma translucent yellow in middle; pubescence (sparse) silvery.

Head

Width in anterior view about 1.2× distance between front ocellus and lower margin of labrum; head width in dorsal view 2× distance between front ocellus and occipital

margin (Fig. 8); frons (Fig. 9) with weak transverse striae and reticulations; ocellocular area reticulate; vertex with 4 strong transverse carinae; other parts of vertex distinctly reticulate and not striate; last one pair of carinae of vertex form a distinct trough on the upper part of temples in side view (Fig. 7); postgena and temples smooth and shiny with faint aciculations; posterior margin of head sharply bordered on sides with middle part without demarcation. POL 2.71× OOL. Head with 5 teeth, anterior one not distinclty stronger than middle pair and separated from middle pair by 1.75× distance between each other. Antenna with scape 2× as long as pedicel; first flagellar segment 1.5× as long as pedicel; second flagellar segment 2× as long as first; third flagellar segment a little more than 2× as long as first but distinctly shorter than combined length of first and second; fourth subequal to third in length.

Mesosoma

Pronotum with 12–15 transcarinae on anterior dorsal half, posterior dorsal half weakly reticulate-striate; sides and ventral part distinctly reticulate. Mesonotum with deep and irregular punctae and reticulations; scutellum faintly reticulate on broad median part, with sparse pits on sides; axillae with fine reticulations, separated from scutellum by deep obligue fovea containing coalescing pits; each axilla separated in anterior part by one or two large deep pits.

Metanotum with a transverse row of 9 pits separated by longitudinal carinae. Mesopleuron finely reticulate (not shagreened as in *priyae*), scattered shallow pits and with moderately dense short silvery pilosity near anterior side. Metapleuron with pleuropodeal fovea and metapleural fovea connected by smooth, deep, lengthy fovea. Propodeum with scattered, large deep pits (Fig. 10) with a broad anterior median unpitted part containing fine transverse microreticulations; interstices mostly broader than diameter of each larger pit; length of propodeum 0.42× length of petiole. Relative median lengths of pronotum: 29; mesoscutum: 5; scutellum: 13; metanotum: 2; propodeum: 18. Forewing length a little more than 4.3× its maximum width. Hind coxa transversely carinate (annulate), interstices between carinae reticulate; length of hind coxa 0.64× length of petiole; hind femur a little longer than hind coxa (37 : 35), a little more than 2.8× as long as it maximum width, outer disc finely reticulate, outer ventral margin with two large teeth and two tubercles anterior to proximal large tooth; central inner side of metatibia as in Fig. 11.

Metasoma

Petiole uniformly annulated, a little shorter than combined length of postpetiolar segments (58 : 69); first postpetiolat tergite a little shorter than 2× second postpetiolar tergite (24 : 13) in dorsal view; second postpetiolar tergite a little longer than 1.4× third postpetiolar tergite; fourth and remaining tergites as in Fig. 7; first postpetiolar tergite faintly reticulate longitudinal basal two-third parts on dorsal side, remaining one-third part with transverse minute striae; remaining tergites (except last tergite) faintly striate; last tergite reticulate (Fig. 7). Terebra a little longer than 1.4× metasoma.

Host

Unknown.

Holotype

Female: India, Kerala, Kumaranelloor (Nr. Edappal), 8.viii.1999, Coll. P. Sudha (BMNH).

DISCUSSION

This new species comes near *D. stom* sp. nov. in general features but differs in having: (1) vertex without median longitudinal black line on dorsal posterior half (in *stom* with a median longitudinal black line on basodorsal half of head); (2) frons (Fig. 9) with weak striae and weak reticulations (in *stom* frons with strong microscuptures) (3) pronotum (Fig. 12) distinctly trans-carinate on anterior dorsal half (in *stom* not trans-carinate but reticulate) and in many other features.

***Diastephanus keralensis* sp. nov. (Figs 14–21)**

Female

Length: 11.12 mm (excluding terebra); terebra length 8.7 mm. Black with following parts as follows: frons below anterior tooth with 3 longitudinal yellow bands or strips; median yellow strip slightly tinged with brown, touching base of anterior (front) tooth; lateral strips closely adjacent to anterior eye margin; lower ends of bands confluent; clypeus and labrum yellow; mandibles yellowish brown with apices black; another yellow strip present close to posterior margin of eye, reaching malar sulcus; temples pale brown; maxillary palp and labial palp brown; eye black with paler patches; front ocellus reflecting black; hind ocelli reflecting dark brown; antenna dark brown with radicula, scape, pedicel, first flagellar segment and second flagellar segment pale brown; posterior margin of pronotum with a slightly paler band; trochanter-brown; femur blackish brown; tibia pale brown with pale yellow colour on ventrobasal part, extending slightly to middle region dorsally; tarsi pale brown with apical part darker. Mid leg: coxa blackish brown; trochanter brown; femur blackish brown; tibia blackish brown with base yellow; metatarsus yellow, following tarsal segments pale brownish yellow except apical blackish brown segment. Hind leg: black with metatarsus and trochanter blackish brown; apex of hypopygium pale brown; terebra black with subapical yellow band. Wings hyaline with veins brown; stigma translucent yellow in middle; sparse pubescence silvery.

Head

Width in anterior view a little more than 1.3× distance between front ocellus and lower labral margin (Fig. 14); head width in dorsal view (Fig. 15) a little more than 1.8× distance between front ocellus and apical margin; frons trans-striate without oblique and longitudinal striae as in the case of *D. priyae*. Ocellocular area obliquely striate;

vertex with 4 transverse carinae followed by fine striae (Fig. 15); striae not forming a median line; posterior margin of head sharply bordered; gena and postorbital region smooth and shiny. POL a little more than 2.3× OOL. Head with 5 teeth, anterior on stronger. Antenna with scape 2× as long as pedicel; second flagellar segment 1.3× as long as first; third a little longer than second; fourth and fifth flagellar segments subequal to length.

Mesosoma

Pronotum weakly reticulate on dorsal side; reticulation a little stronger on sides; pronotum not striate dorsally (Fig. 17); mesoscutum faintly reticulate, shiny, anterior half clearly separated by fovea which is deeper on sides, posterior half with a median longitudinal ridge; axillae separated by a deep pit infront of scutellum; axilla faintly but distinctly reticulate, shiny. Scutellum shiny with faint reticulations (visible only under certain lights); axilla separated from scutellum by oblique row of irregular pits; metanotum with six deep pits, each pit separated by longitudinal ridges; mesopleuron shagreened with a few scattered shallow pit-like depressions, with minute silvery dense pubescence on anterior side; metapleuron distinctly microsculptured (Fig. 18); post-foveolar are microsculptured, with 3 carinae; interfoveolar area microsculptured, inside of fovea mostly smooth with faint microsculptures; metapleuron open below petiolar foramen. Propodeum (Fig. 19) with large pits, interstices transversely reticulate, inside of pits distinctly microsculptured, length of propodeum 0.37× length of petiole. Relative length of pronotum: 19; mesoscutum: 5; scutellum: 9; metanotum: 3; propodeum: 14. Forewing length 4.76× its maximum width; hind coxa carinate-punctate basally, rest of portions circularly annulate; length of hind coxa 0.67× length of petiole; hind femur (Fig. 20) a little shorter than hind coxa (19 : 21), 3× as long as its maximum width, ventral margin with 3 large teeth and a tubercle anterior to basal tooth; hind tibia median part as in Fig. 21).

Metasoma

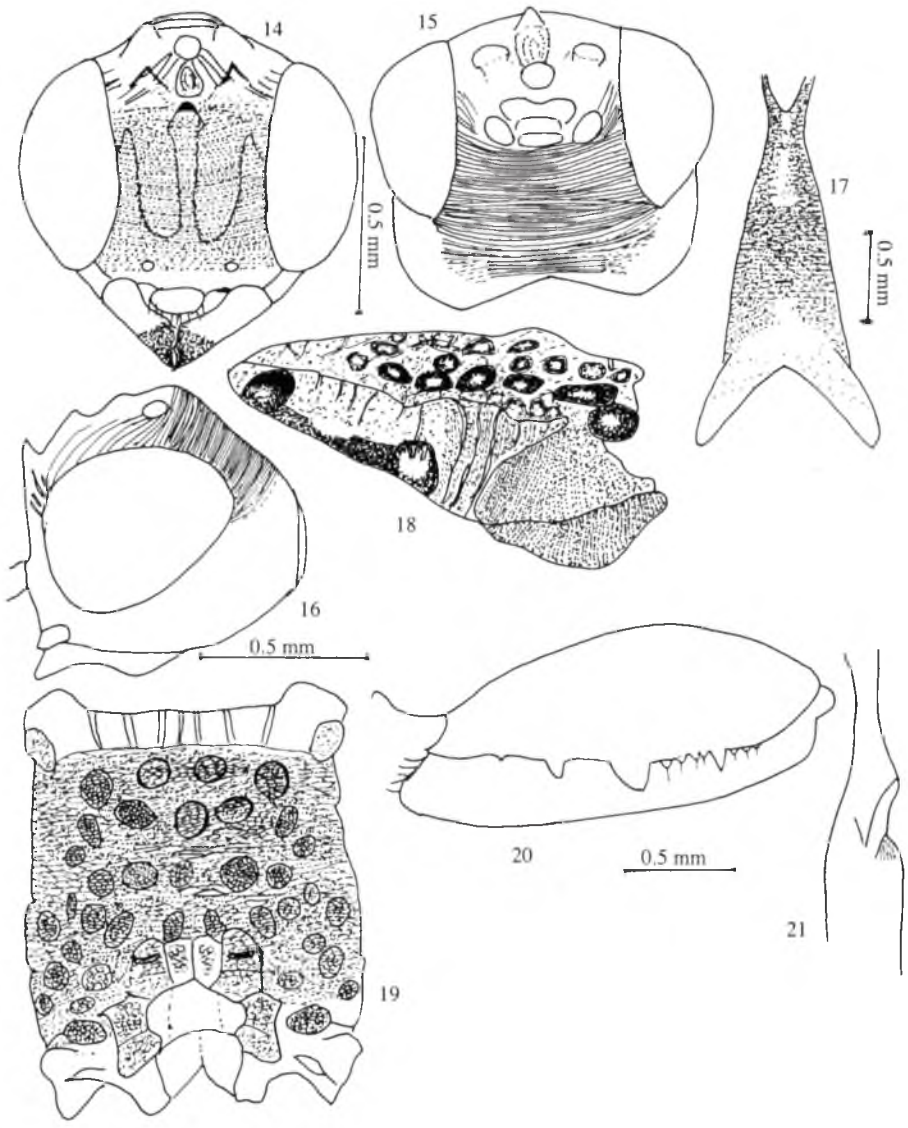
Petiole uniformly anulated, its length a little more than 1.19× length of combined length of postpetiolar segments; first postpetiolar tergite a little longer than 2× length of second post-petiolar tergite in dorsal view; second postpetiolar tergite slightly longer than third; first postpetiolar tergite with faint transverse striae (visible only in certain lights) on posterior dorsal half, anterior half with longitudinal reticulations; following tergites faintly striate transversely except last tergite which is distinctly reticulate; posterior margin of pygidium emarginate posteriorly. Terebra 1.28× as long as metasoma (excluding terebra).

Male

Unknown.

Host

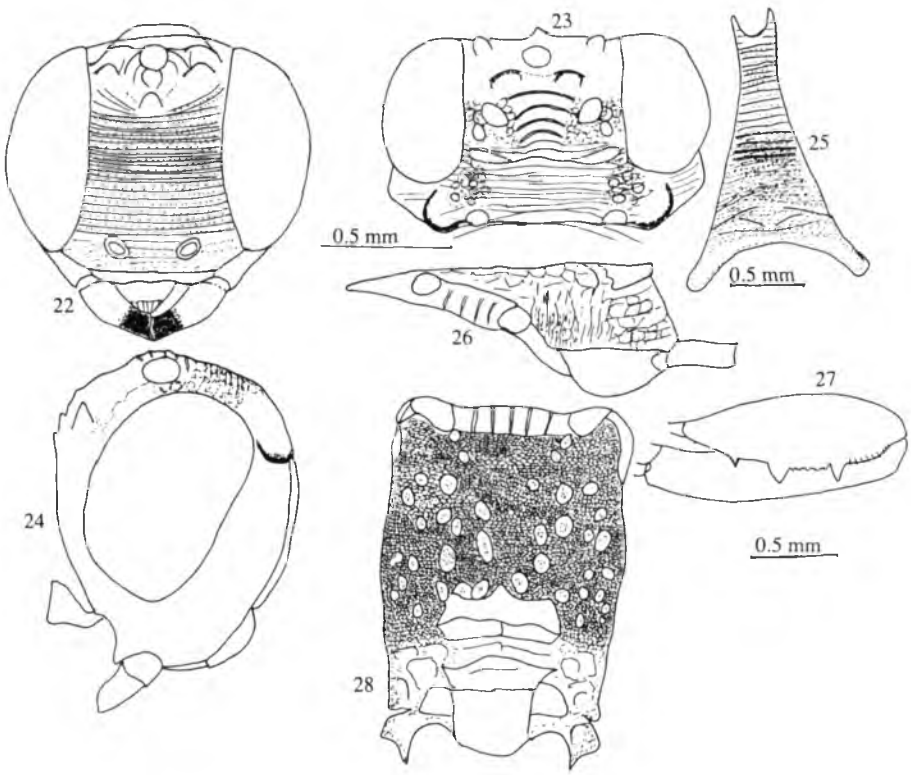
Unkown.



Figs 14–21: *D. keralensis* sp.nov (Female). 14. Head anterior view; 15. Head dorsal view; 16. Head lateral view; 17. Pronotum dorsal view; 18. Matapleuron lateral view; 19. Propodeum; 20. Hind femur; 21. Middle part of hind tibia inner view.

Holotype

India, Kerala, Edapal, 10.x.1999, Coll. P. Sudha (ZSIC).



Figs 22–28: *Diastephanus anupam* sp. nov. (Female): 22. Head anterior view; 23. Head dorsalview; 24. Head lateral view; 25. Pronotum dorsal view; 26. Metapleuron lateral view; 27. Hind femur; 28. Propodeum.

DISCUSSION

This species comes near *Diastephanus daccaensis* sp. nov. in general appearance but differs from *daccaensis* by having features discussed under *D. daccaensis* elsewhere in this paper.

Diastephanus anupam sp. nov. (Figs 22–28)

Female

Length: 10.4 mm (excluding terebra); terebra length 8.6 mm. Black with following parts as follows: ventral half of frons brownish yellow, becoming more yellowish towards ventral side; apical half of mandibles black; gena and temples brownish yellow; maxillary palp and labial palp brown; eye black with paler patches around margin; ocelli reflecting blackish brown; antenna dark brown with scape, pedicel and first flagellar segment brownish yellow; ventral part of pronotum dark brown; posterior margin of pronotum with slightly paler band. Fore leg brown with femur, apical half of tibia, apical tarsus and pretarsus blackish brown middle leg brownish

black with trochanter, base of femur and base of tibia pale brown; metatarasus pale brownish yellow; remaining tarsal segments and pretarsus dark brown. Hind leg black with trochanter and tarsal segments and pretarsus pale brown; tegula dark brown; wings hyaline with veins pale brown, stigma brown with paler margins; apical part of hypopygium pale brown; terebra brownish black without any yellow or white bands. Pubescence silvery.

Head

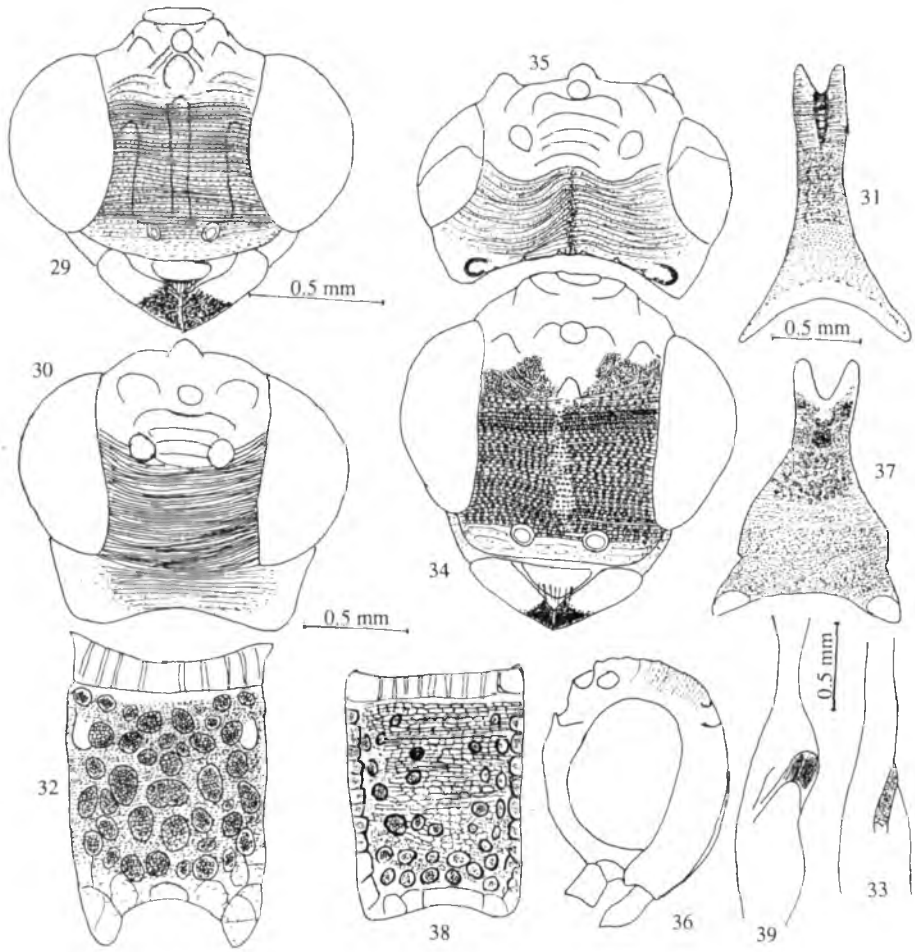
Width in anterior view (Fig. 22) 1.3× distance between front ocellus and lower margin of labrum; head width in dorsal view (Fig. 23) a little more than 2× distance between front ocellus and occipital margin; frons trans-striate (Fig. 22) with interstices between striae microsculptured, without oblique striae as in *priyae*. Ocellocular area not striate, with large pits, inside pits and interstices reticulate. Vertex with 4 strong carinae (Fig. 23) followed by transverse striae, striae not forming median line, reticulo-punctate on sides; posterior margin of occiput smooth. POL a little shorter than 4× OOL. Head with 5 teeth; temples with a pit and elevated ridge posteriorly (Fig. 24). Antenna with scape a little more than 1.6× as long as pedicel; second flagellar segment a little more than 2× as long as first; third flagellar segment a little more than 1.2× as long as second; fourth flagellar segment slightly longer than fourth; fifth flagellar segment shorter than fourth.

Mesosoma

Pronotum (Fig. 25) strongly trans-carinate which become tras-reticulate posteriorly. Mesoscutum distinctly reticulate in anterior half, posterior half with deep fovea between the arms of a somewhat '*v*' shaped carinae, without a median carina; axillae separated from each other by deep fovea in front of scutellum; axilla faintly and longitudinally striate, shiny; scutellum finely reticulate; metanotum with 8 or 9 deep pits, each separated by longitudinal reidge; mesopleuron shagreened with several scattered pits, with silvery pubescence on anterior half; metapleuron rugosoreticulate; post foveolar area as in Fig. 26; interfoveolar area with several trans-carinae, interstices of carinae rugulose; metapleuron open below petiolar foramen. Propodeum (Fig. 29) with pits shallow, widely scattered, interstices microreticulate, not transversely striate or reticulate, inside of pits faintly reticulate (reticulations visible only under certain lights); length of propodeum about 0.37× length of petiole (15 : 41). Relative lengths of pronotum: 20; mesoscutum: 3; scutellum: 8; metanotum: 2; propodeum: 5; petiole: 41; hind coxa transversely carinate; length of hind coxa 0.68× length of petiole. Hind femur (Fig. 27) 2.95× as long as its width, ventral margin with 3 large teeth, without any distinct tubercles basal to proximal large tooth; central region of metatibia as in Fig. 28.

Mesosoma

Pronotum with strong transcarinae which become transreticulate posteriorly (Fig. 25). Mesoscutum distinctly reticulate in anterior half, posterior half with a deep fovea



Figs 29–33: *D. daccaensis* sp. nov. (Female): 29. Head anterior view; 30. Head dorsal view; 31. Pronotum dorsal view; 32. Propodeum; 33. Middle part of hind tibia inner view. Figs 34–39: *D. stom* sp. nov. (Female): 34. Head anterior view; 35. Head dorsal view; 36. Head lateral view; 37. Pronotum; 38. Propodeum; 39. Middle part of hind tibia inner view.

between the arms of somewhat '*v*' shaped carinae, without a median carina; axillae separated from each other by deep fovea infront of scutellum; axilla faintly and longitudinally striate, shiny; scutellum finely reticulate; metanotum with 8 or 9 deep pits, each pit separated by longitudinal strong ridge; mesopleuron shagreened with several scattered pits, with silvery pubescence on anterior half; metapleuron rugosoreticulate; postfoveolar area as in Fig. 26; interfoveolar area with several cross carinae, interstices between carinae rugulose; metapleuron open below petiolar foramen. Propodeum (Fig. 29) shallow pits, widely scattered, interstices microreticulate and microsculptured, not transversely reticulate, inside of pits faintly reticulate

(reticulations visible only under certain lights); length of propodeum about 0.37× length of petiole (15 : 41). Relative length of pronotum: 20; mesosctum: 3; scutellum: 8; metanotum: 2; propodeum: 15; petiole: 41; hind coxa transversely carinate; length of hind coxa 0.68× length of petiole. Hind femur (Fig. 27) 2.95× as long as its width; ventral margin with 3 large teeth, without any distinct tubercles anterior to basal tooth.

Metasoma

Petiole uniformly annulated, its length 1.16× length of postpetiolar tergites combined; first postpetiolar tergite 2.5× length of second postpetiolar tergite but subequal to fourth tergite. First postpetiolar tergite with faint transverse, closely packed aciculations on posterior half in dorssal view, anterior half longitudinally reticulate wiith base strongly rugose and sculptured; following tergites (except last one) closely and transversely aciculate; last gastral tergite strongly reticulate; posterior margin of pygidium notched on dorsal view; terebra a little more than 1.37× combined length of petiole and remaining part of metasoma.

Male

Unknown.

Host

Unknown.

Holotype

Female: India, Arunachel Pradesh, W. Kameng, Bhalukpung, 25.x.1997. Coll. T. C. Narendran (ZSIC).

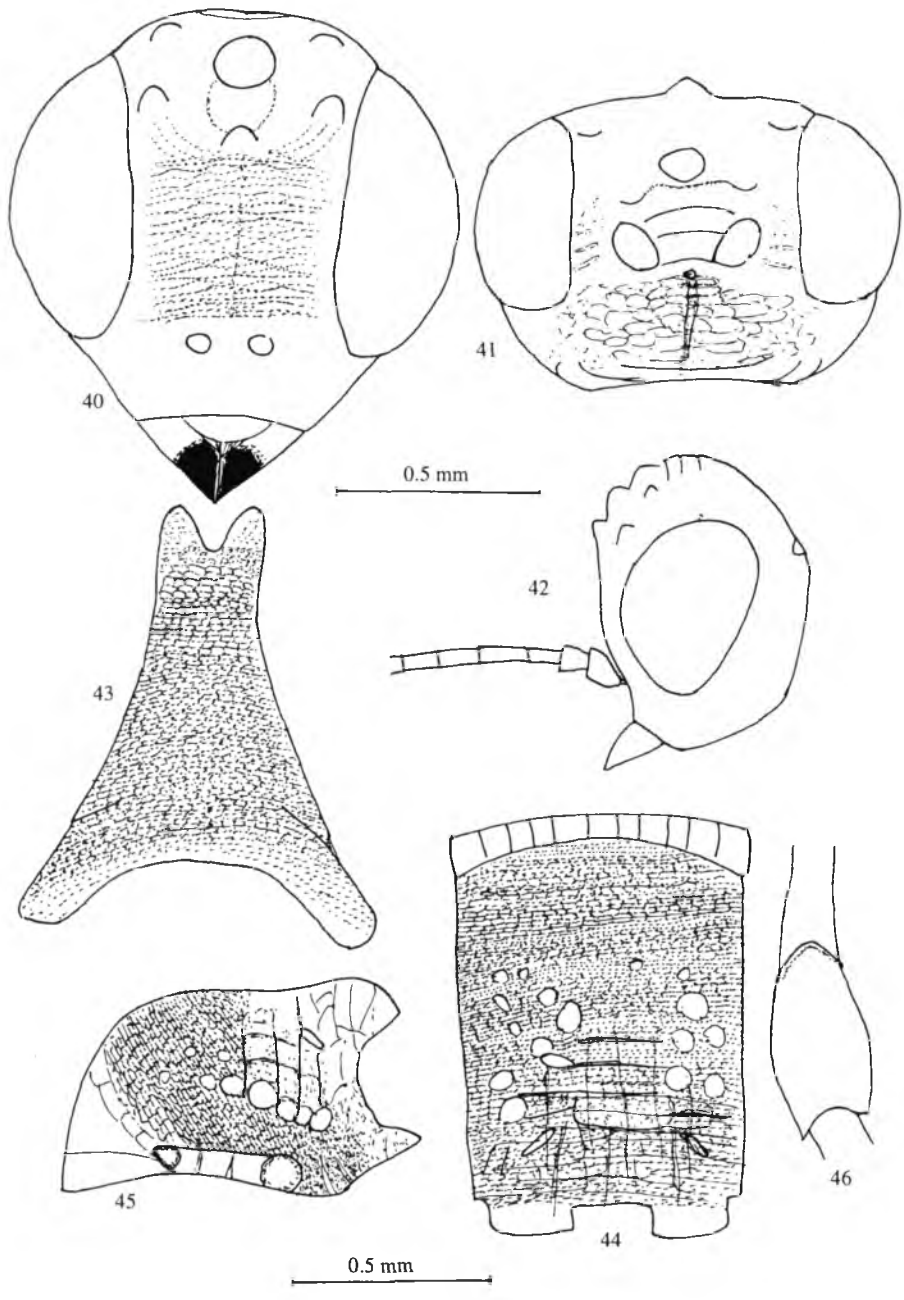
DISCUSSION

This new species comes near *Diastephanus szepligetii* Enderlein (described from West Africa) in general colour but differs from *D. szepligetii* in having: (1) vertex with 4 transverse carinae (in *szepligetii* vertex with 2 transverse carinae); (2) pronotum with distinct transverse carinae and striae (pronotum smooth and polished in *szepligetii*); (3) hind coxa transversely carinate (punctate in *szepligetii*; and in several other features.

***Diastephanus daccaensis* sp. nov. (Figs 29–33)**

Female

Length: 10.69 mm (excluding terebra); terebra length 8.19 mm. Black with following parts as follows: frons below anterior tooth with 3 longitudinal bands (Fig. 29), median longitudinal band touching base of front tooth, lateral bands closely adjacent to anterior eye margin, lower ends of bands confluent; clypeus and labrum yellow; mandibles yellow with apices black; gena pale brown with a yellow longitudinal band



Figs 40–46. *D. burmaensis* sp. nov (Female): 40. Head anterior view; 41. Head dorsal view; 42. Head side view; 43. Pronotum dorsal view; 44. Propodeum dorsal view; 45. Metapleuron lateral view; 46. Mid region of hind tibia inner view.

behind posterior margin of eye; temples pale brown; maxillary palp and labial palp brown; eye black with paler patches; ocelli reflecting blackish red; antenna brown with scape and pedicel yellow, funicular segments paler towards basal segments. Fore leg: coxa and trochanter pale brown; femur dark brown; tibia pale brown, tarsi pale yellow except darker distal segment and pretarsus. Mid leg: similar to fore leg except following metatarsus brown and mid coxa dark brown. Hind leg: coxa black; trochanter, femur and tibia dark brown; metatarsus brown, remaining tarsal parts dark brown. Metasoma black with apex of hypopygium yellow; terbra brown with subapical yellow band, apex black. Wings hyaline with veins brown, stigma dark brown with paler middle part. Pubescence silvery.

Head

Width in anterior view (Fig. 29) 1.5× distance between front ocellus and lower margin of labrum; head width in dorsal view 1.63× distance between front ocellus and occipital margin; frons trans-striate; ocellocular are obliquely striate; vertex (Fig. 30) with 4 transverse carinae followed by fine striae (Fig. 30); striae not forming a median line; posterior margin of head sharply bordered; gena and postorbital region smooth and shiny. POL 1.7× OOL; head with five teeth. Antenna with scape 1.5× as long as pedicel; second flagellar segment 1.5× as long as first; length of third tergite equal to second; fourth longer than fifth.

Mesosoma

Pronotum with a median fovea anteriorly; strongly reticulate on dorsal as well as lateral side, reticulation becoming somewhat striate on posterior half. Mesoscutum with anterior half strongly reticulate, posterior half with a median longitudinal ridge; axilla distinctly eticulate, not smooth, scutellum with distinct reticulations; metanotum with 8–9 deep pits; mesopleuron shagreened with a few scattered pits, with minute silvery dense pubescence on anterior side; metapleuron distinctly microsculptured; post foveolar area with 3 weak carinae, interfoveolar are microsculptured; metapleuron open below petiolar foramen. Propodeum (Fig. 32) with large pits, interstices and inside of pits reticulate. Length of propodeum 0.3× length of petiole. Relative length of pronotum: 19; mesoscutum: 4; scutellum: 9; metanotum: 2; propodeum: 15. Forewing length 4.5× maximum width; hind coxa irregularly carinate-punctate basally, rest of coxa circularly carinate; length of hind coxa 0.46× length of petiole; hind femur subequal in length of hind coxa, 3× as long as its width, ventral margin with 3 large teeth with a tubercle anterior to basal tooth; central depressed area of hind tibia reticulate (Fig. 33); hind metatarsus with spines on metatrasus on ventral margin.

Metasoma

Petiole uniformly anulated, its length 1.1× length of postpetiolar part; first postpetiolar tergite 2× length of second postpetiolar tergite in dorsal view; second a little longer than third; first postpetiolar tergite as in the case of *D. keralensis*. Posterior margin of pygidium emarginate posteriorly. Terebra 1.17× length of metasoma.

Male

Unknown.

Host

Unknown.

Holotype

BANGALADESH, Dacca (original label shows 'India: Dacca' ix.1945, Coll. D. Leston (BMNH Reg. No. 1945–86) (BMNH).

DISCUSSION

D. daccaensis resembles *D. keralensis* very closely in general colour pattern and in many other morphological features. However *D. daccaensis* differs from *D. keralensis* in having: (1) pronotum with a median fovea anteriorly (in *keralensis* no such fovea present); (2) pronotum distinctly and strongly reticulate-striate on dorsal part and on sides (in *keralensis* pronotum very weakly and faintly reticulate on dorsal side); (3) POL 1.7× OOL (in *keralensis* POL 2.3× OOL); (4) antennal scape 1.5× as long as pedicel (in *keralensis* scape 2× as long as pedicel); (5) anterior half of mesoscutum, axilla and scutellum clearly and distinctly reticulate (in *keralensis* reticulation hardly visible in certain lighting, surface mostly smooth); (6) length of hind coxa 0.46× length of petiole (in *keralensis* length of hind coxa 0.67× length of petiole); petiole length 1.1× length of remaining part of metasoma (in *keralensis* petiole length 1.2× length of postpetiolar segments combined) and (8) terebra 1.17× length of postpetiolar segments combined.

***Diastephanus stom* sp. nov. (Figs 34–39)**

Female

Length 6.79 mm (excluding terebra); terebra 5.36 mm. Blackish brown with following parts as follows: head with are below front tooth brownish yellow; area above front tooth darker; scape, pedicel, first and second flagellar segments pale brownish yellow, remaining antennal segments dark brown; gena yellow; eye grey with black patches; maxillary and labial palp brown with basal segments paler; mandibles yellow with apex dark brown; ventral part of pronotum, fore coxa and fore trochanter pale brownish yellow; posterior margin of pronotum paler. Fore femur and tibia brown with basodorsal half of tibia paler; fore metatarsus pale brown, remaining tarsal segments and pretarsus darker. Mid coxa and mid trochanter pale brown; mid femur brown with base slightly paler; mid tibia brown with a subbasal yellow spot; mid metatarsus pale yellow; second mid tarsal segment pale yellowish brown, remaining tarsal segments gradually increasing in dark colour. Hind leg with coxa black; femur liver brown, basal larger tooth slightly paler; hind tibia black; tarsal segments pale brown; terebra brown with apex slightly darker, without a yellowish or whitish band. Wings hyaline, stigma and veins pale yellow with margins darker; pubescence of mesopleura silvery.

Head

Width in anterior view (Fig. 34) 1.33× distance between front ocellus and lower margin of labrum; head width in dorsal view (Fig. 35) 2× distance between front ocellus and occipital margin; frons trans-striate with strong microsculptures (Fig. 34); all frontal teeth relatively small; vertex (Fig. 35) with five transverse carinae followed by transverse striae with a median darker longitudinal band; posterior margin of head irregularly margined in dorsal view; gena and postorbital region smooth and shiny; temples with a slight elevated ridge posteriorly in side view. POL a little more than 3× OOL. Antenna with scape 1.6× as long as pedicel; second flagellar segment 1.7× as long as first; third a little longer than second and equal to fourth; fifth shorter than fourth but longer than second.

Mesosoma

Pronotum with distinct reticulations (Fig. 37), not striate, ecarinate; mesoscutum reticulate on anterior half (visible part); posterior half with a median longitudinal ridge; sides reticulopunctate and irregularly carinate; axillae separated from each other in front of scutellum with 3 large pits; axillae smooth with faint aciculations, without any pit; scutellum smooth, faintly reticulate (visible only under certain lights) and with a few small scattered pits on sides. Metanotum with 10 deep pits (Fig. 38); mesopleuron mostly striate-reticulate; metapleuron reticulate; metapleuron open below petiolar foramen. Propodeum (Fig. 38) with very large interstices; inside of pits reticulate length of propodeum 0.52× length of petiole. Relative length of pronotum: 23; mesoscutum 3.75; scutellum 10; metanotum 2; propodeum 17. Forewing length 3.5× its maximum width; hind coxa circularly carinate; length of hind coxa 0.81× length of petiole; hind femur subequal in length of hind coxa, 3× as long as its width, ventral margin with two large teeth and a basal tubercle; hind femur distinctly and strongly reticulate on outer disc; central inner depression of hind tibia obliquely striate.

Metasoma

petiole irregularly annulated, its length 0.67× combined length of postpetiolar tergites (20 : 30); first postpetiolar tergite a little shorter than 2× length of second postpetiolar tergite; third postpetiolar tergite a little shorter than second. First postpetiolar tergite faintly and longitudinally aciculate on anterior half dorsally, posterior half faintly trans-striate; last postpetiolar tergite distinclty reticulate; pygidium notched posteriorly on dorsal side; terebra 1.4× as metasoma.

Male

Unknown.

Host

Unknown.

Holotype

Female: India, Arunachal Pradesh, W. Kameng, Bhalukpung, 25.x.1977, Coll. T. C. Narendran (BMNH).

DISCUSSION

This new species comes near *D. alutaceus* Morley in general colour but *D. alutaceus* differs from this new species in having: (1) terebra shorter than 1.3× length of metasoma; (2) third postpetiolar tergite with a pair of black spots on dorsal side; (3) first postpetiolar tergite with a circular black spot at each side and (4) neck with a discal longitudinal sulcus.

***Diastephanus burmaensis* sp. nov. (Figs 40–46)**

Female

Length: 11.66 mm (excluding terebra); terebra length 3.66 mm. Light brown with following parts as follows: frons yellowish brown; gena yellow; pronotum darker on dorsal median part, posterior margin pale yellow; bases of fore tibia and mid tibia paler; hind leg and two large basal teeth of hind femur pale yellow; mesosoma black with scutellum, innner sides of axillae and posterior side of propodeum brown; petiole brown; postpetiolar segments brown with a yellow band on second postpetiolar segment, remaining segments darker, hypopygium pale brown; terebra brown without a subapical band; wings hyaline, veins pale brown. Pubescence on metapleuron silvery.

Head

(Fig. 40) Width in anterior view 1.24× distance between front ocellus and distal margin of labrum; width in dorsal view 2.15× distance between front ocellus and posterior occipital margin; frons weakly reticulate, without distinct oblique carinae. Vertex with 3 transverse carinae followed by large irregular pits and a median shallow longitudinal fovea; posterior margin of head not sharply bordered; gena and postorbital region smooth and shiny; temples with raised pit in side view; POL 1.4× OOL. Head with 5 teeth, anterior one stronger than others. Antenna with scape 1.6× as long as pedicel; second flagellar segment a little longer than 1.6× length of first flagellar segment; third shorter than second; fourth shorter than third; fifth subequal in length to fourth.

Mesosoma

Pronotum reticulate (Fig. 43), not carinate or striate; mesoscutum distinctly reticulate and divided by median carina on anterior half, posterior half irregularly pitted; axillae and scutellum distinctly reticulate longitudinally; metanotum with 11 or 12 deep pits; mesopleura finely reticulate; metapleuron (Fig. 45) disntinctly reticulate, post foveolar area microsculptured, interfoveolar area smooth; metapleuron open below petiolar

foramen. Propodeum (Fig. 44) with scattered sparse pits, interstices broad, distinctly reticulate. Relative lengths of pronotum 18; mesoscutum 4; scutellum 10; metanotum 2; propodeum 21. Forewing length a little more than 4× its maximum width; hind coxa annulate with interstices microsculptured; length of hind coxa 0.8× length of petiole; hind femur as long as hind coxa, its length a little less than 3× its maximum width, ventral margin with 2 large teeth, inbetween large teeth with 3 tubercles; anterior area to basal tooth of hind femur with a basal tubercle. Inner middle region of hind tibia as in Fig. 46.

Metasoma

Petiole weakly and irregularly annulate, shorter than combined length of postpetiolar segments (excluding terebra); first postpetiolar tergite 2× as long as second postpetiolar segment; first postpetiolar tergite longitudinally reticulate; remaining tergites transversely reticulate, not striate. Last tergite microsculptured; posterior margin of pygidium emarginate posteriorly. Terebra 1.1× as long as metasoma, 2× as long as metasoma excluding petiole.

Male

Length 5.4 mm. Similar to female in general but differs in having petiole 1.14× longer than combined length of postpetiolar segments together.

Host

ex *Tectona grandis*.

Holotype

Female, Myanmar(=Burma), Pyinmana, Yeni Reserve. 17.vi.1934, Coll. M. H. Desai (BMNH). Paratype: 1 male of same data as for holotype (BMNH) except date 19.vi.1934.

DISCUSSION

This new species come near *D. sudhae* in general appearance but can be separated by using the key given in this paper. The male of this species resembles the male of *D. chinnarensis* in having second postpetiolar segment with yellow band but differs from *chinnarensis* in having petiole 1.14× as long as combined length of postpetiolar segments, in having scutellum and axillae not convex and in having pronotum, petiole, hind femur etc. pale brown.

***Diastephanus frontilinea* Morley**

Diastephanus frontilinea Morley (1917) *Entomologist*, **1**: 109 (IART)

Diagnosis

Female: Length 10.5 mm; terebra 9 mm. Black; mouth parts; inner and outer orbits testaceous; a longitudinal line on centre of frons and head teeth rufous; anterior tibia testaceous and hind tarsi red. Frons faintly reticulate; vertex longitudinally aciculate; occiput very finely and closely trasaciculate. Antenna with first and second flagellar segment equal in length and shorter than third. Pronotum multicarinate, semiannular, smooth and shiny. Scutellum smooth and shiny. Metapleuron smooth and finely subaciculate, separated by a strongly marked sulcus from propodeum which is coriaceous between very large and partly confluent pits. Hind femur bidentate. Petiole transaciculate, longer than combined length of postpetiolar segments; terebra with subapical white band, shorter than body but longer than metasoma.

Male

Unknown.

Host

Unknown.

Distribution

Bangaladesh and East India (Assam).

DISCUSSION

I have not come accross this species so far and the above given diagnosis is based on Elliott's description (Elliot, 1922). This species can be separated from other Indian species by using the key given in this paper.

***Diastephanus bilineatus* Elliott**

Diastephanus bilineatus Elliott (1919) *Entomologist* **I(2)**: 162

Diagnosis

Female: Length 8–8.85 mm (excluding terebra); terebra 7 mm. Black; head rufescent, mandibles except extreme apex, frons centrally and broadly and orbits upto the level of front tooth flavous; hypopygium at tip white; terebra with subapical pale band. Anterior knees pale rufescent, hind legs darker with knees and metatarsus pale; central femoral tooth white. Frons finely trans-striate; two carinae between posterior ocelli, all frontal teeth distinct; occiput margined; second flagellar segment 1.5× as long as first, third longer than second but shorter than combined length of first and second together. Pronotum finely trans-striate on anterior half; metapleuron and propodeum cribrate punctate, not separated; hind femur tridentate; petiole as long as rest of metasoma; terebra longer than metasoma; petiole longer than combined length of postpetiolar segments.

Male

Unknown.

Host

Unknown.

Distribution

India (Bihar, Bengal).

DISCUSSION

We have not come across this species so far and the above given diagnosis is based on Elliott's description (Elliott, 1922). *D. bilineatus* comes near *D. anupam* in general appearance but differs from the latter in having: (1) terebra with a subapical pale band, (2) central tooth of hind femur white and (3) petiole as long as gaster.

Diastephanus chinnarensis **Sureshan**

Diastephanus chinnarensis Sureshan (1999) *Bioved* 3: 89–92 (ZSIC-examined)

Diagnosis

Male: Length 7 mm. Black with following parts as follows: frons completely yellow with tips of frontal teeth reddish brown; eye grey with posterior margin pale yellow; ocelli reflecting black; apices of mandibles black; temples pale reddish brown; gena yellow; pronotum with pale brownish yellow on area adjacent to posterior margin on sides and on dorsal posterior area. Fore and mid legs pale brown with femora slightly darker; distal tarsal segment and pretarsus brown; hind femur and tibia brownish black with both larger teeth white; second postpetiolar segment with yellow band dorsolaterally. Frons distinctly trans-striate; vertex with 2 trans-carinae; posterior to carinae rugosely and irregularly recticulo-punctate and with broken carinae; occipital margin not bordered; pronotum deeply reticulate, not trans-carinate or striate; axillae and scutellum strongly reticulate; metapleuron distinctly and strongly reticulate; propodeum anterior dorsal half strongly reticulate with hardly one or two pits, posterior transversely and irregularly carinate and pitted. Petiole longer than combined length of postpetiolar segments. First petiolar tergite weakly and longitudinally reticulate; remaining tergites transversly and weakly reticulate, not striate.

Female

Unknown.

Male

Unknown.

Remarks

The above description is based on the holotype.

DISCUSSION

D. flavifrons Elliott resembles *D. chinnarensis* in general appearance but can be separated from *chinnarensis* in having: (1) vertex trans-carinate; (2) second flagellar segment 2× as long as first; (3) petiole as long as rest of metasoma and in several other features.

***Diastephanus wayanadensis* Sureshan and Narendran (Figs 5 and 6)**

Diastephanus wayanadensis Sureshan and Narendran (1997) *Geobis New Reports* **16**: 25–26 (ZSIC-examined)

Diagnosis

Female: 10.7 mm (excluding terebra); terebra length 10.8 mm. Black, with following parts as follows: a small yellow brown patch on either side of frons near base of antennae, close to lower anterior eye margin and another similar but bigger patch close to posterior lower eye margin near gena; clypeus, mandibles (except darker tips) and mouth parts pale yellowish brown; eye greyish brown; ocelli pale white; fore and mid legs dark brown except on trochanters and tarsi pale; hind leg black except tip of trochanter and tarsi pale red; forewing stigma translucent yellow in middle. Terebra with pale subapical band; frons trans-striate (Fig. 6); vertex with 3 trans-carinae (Fig. 5); pronotum tras-carinate on anterior half and trans-striate on remaining part, with a median longitudinal line or groove. Scutellum and axilla smooth and polished; propodeum with broad and deep pits, sparse on anterior part, interstices shagreened; petiole uniformly trans-carinate, a little shorter than remaining part of metasoma; length of terebra 3× length of post-petiolar segments combined.

Male

Unknown.

Host

Unknown.

Remarks

The above diagnosis is based on the type.

DISCUSSION

D. wayanadensis can be separated from all other Indian species by the key provided below.

Key to species of *Diastephanus* Enderlein of Indian subcontinent

1. Terebra with subbasal pale band 2
- Terebra without subbasal paler band 6
2. Hind femur with 3 large teeth on ventral margin 3
- Hind femur with 2 large teeth on ventral margin ..... *frontilinea* Morley
3. Petiole longer than combined length of postpetiolar segments 4
- Petiole as long as or shorter than combined length of postpetiolar segments .. 5
4. Pronotum with a median fovea or depression anteriorly; distinctly and strongly striato-reticulate on dorsal side; reticulation of axilla and scutellum well pronounced; hind coxa shorter than 0.5× length of petiole; terebra longer than 1.2× length of postpetiolar segments combined ..... *daccaensis* sp. nov.
- Pronotum without a median fovea of depression anteriorly, faintly reticulate, mostly smooth on dorsal side; reticulation of axilla and scutellum hardly distinct; hind coxa longer than 0.6× length of petiole; terebra longer than 1.2× length of postpetiolar segments combined ..... *keralensis* sp. nov.
5. Upper part of frons with distinct oblique carinae (Fig. 2); vertex (Fig. 3) with 4 cross carinae; all three teeth of hind femur black; ..... *priyae* sp. nov.
- Frons without such oblique carinae as in above alternate; vertex with fewer cross carinae; middle hind femoral tooth paler 6
6. Vertex with 3 cross carinae; petiole shorter than combined length of postpetiolar segments ..... *wayanadensis* Sureshan and Narendran
- Vertex with 2 cross carinae; petiole as long as combined length of postpetiolar segments ..... *bilineatus* Elliott
7. Hind femur with 2 large teeth on ventral margin 8
- Hind femur with 3 large teeth on ventral margin ..... *anupam* sp. nov.
8. Vertex with characteristic wavy cross striate (Figs 35); frons strongly transstriate and interstices strongly microsculptured (Fig. 34); terebra 1.4× as long as metasoma ..... *stom* sp. nov.
- Vertex not as above, without distinct cross striae but with irregular pits (Figs 8 and 41); frons weakly striate (Figs 9 and 40); terebra different ..... 9.
9. Pronotum strongly transcarinate on anterior half (Fig. 12); vertex without longitudinal fovea (Fig. 8) or line; terebra a little longer than 1.4× metasoma ..... *sudhae* sp. nov.
- Pronotum reticulate, not transcarinate (Fig. 43); vertex with a median shallow longitudinal fovea (Fig. 41); terebra 1.1× as long as metasoma ..... *burmaensis* sp. nov.

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Studies on the mosquito fauna in a Japanese encephalitis prone area in Kerala, India

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ABSTRACT: Mosquito fauna was studied during an explosive insular outbreak of Japanese encephalitis which occurred for the first time in 1996 in Kuttanadu, Kerala, India. A total of twenty-six species belonging to six genera of mosquitoes *viz.*, *Aedes*, *Anopheles*, *Armigeres*, *Culex Coquillettidia* and *Mansonia* were collected. Among these *Culex* species were dominant, representing 76.6% of total collection. A total of 169,054 mosquito specimens were collected of which *Cx. tritaeniorhynchus* was the most dominant species represented with 64.3% of the total collection. The fauna list includes six species which are considered to be having medical importance in this region, namely *Cx. gelidus*, *Cx. quinquefasciatus*, *Cx. tritaeniorhynchus*, *Ma. annulifera*, *ma, indiana* and *Ma. uniformis*. The remaining twenty species accounted for 1.4% which are considered to be of no medical importance in Kuttanadu region.

KEYWORDS: Kuttanadu, *Cx. tritaeniorhynchus*, *Cx. quinquefasciatus*, Cx. *gelidus*, *Mansonia*

INTRODUCTION

Cherthalai Taluk, in Allepppey district which lies in the Kuttanadu region has been considered as hot-bed of Brugian filariasis. The scourge of the disease in this area is well documented and species of *Mansonia* were incriminated as the vectors of Brugian filariasis in this region (Iyengar, 1938). Sabesan *et al.* (1991) studied the seasonal abundance, biting behaviour of *Mansonia* species and their relative role in the transmission of Brugian filariasis in this region. An explosive insular outbreak of encephalitis cases occurred in Kuttanadu in 1996 and during the outbreak 48 cases were recorded between January and April which was diagnosed to be Japanese encephalitis (JE) by the National Institute of Virology (NIV), Pune, India (unpublished data). Preliminary entomological investigations were made in 1996 and JE virus has been isolated from the wild caught mosquitoes (Dhanda *et al.*, 1997). When sporadic cases of JE were reported continuously in 1997 and 1998, entomological studies

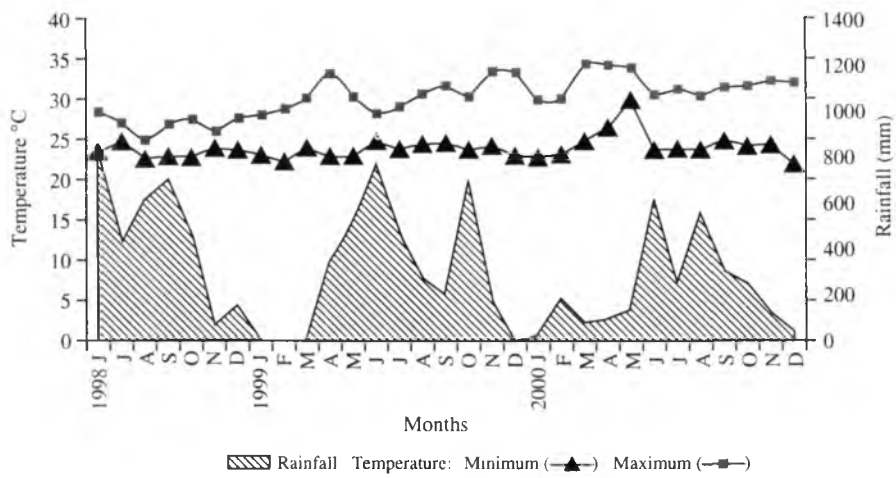

FIGURE 1. Climatic condition of Kuttanadu.

were carried out during JE outbreak and, thereafter, a longitudinal study from June 1998 to February 2001 was undertaken to know more in detail about the ecology of mosquitoes which will facilitate to develop appropriate entomological surveillance and to formulate suitable vector control strategies. In this study an attempt is made to list out the mosquito fauna collected in between January 1996 and February 2001, with notes on the bionomics of the species encountered.

MATERIALS AND METHODS

Study area

Entomological collections were made once in a month in each of six selected index villages where at least one confirmed case of JE had occurred in 1996. The Kuttanadu region is lying 0.5–2 m below mean sea level (MSL) around Vembanadu lake (9°28′ and 10°10′ N and 76°13′ and 31′ E) in Alleppey and Kottayam districts of Kerala, South India. The whole area is waterlogged with innumerable water bodies, infested with aquatic weeds. Kuttanadu is a warm, humid region with fairly uniform temperature throughout the year ranging from 22°C to 34.3°C. Relative humidity generally is very high, ranging from 70 to 90 per cent. The area receives heavy rainfall about 3000 mm annually from both the Southwest and the Northeast monsoons with the maximum number of rainy days occurring from May to August (18–21 rainy days/month) and with one or two dry months during January to March (Fig. 1).

Entomological survey

Mosquito abundance was monitored by carrying out indoor and outdoor resting, and all night landing collections. Resting indoor (IRC) and outdoor collections

(ORC) were made in 3–4 man hours/village using hand catch method spending 15 minutes/house and covering 12 houses randomly in a village. Outdoor resting mosquitoes were collected under the vegetations around cattle sheds and pig sties using drop net methods. All night landing collections (ANLC) were made in one fixed village (Kavalam) once in a month, mosquitoes were caught while landing on human volunteer bait between 18.00 and 06.00 h on the ensuing day. Dusk collection (DC) were made around cattle sheds and pig sties. The abundance of mosquitoes in IRC, ORC and DC was expressed as number of female mosquitoes collected per man hour (PMH) density and in ANLC as human biting index (HBI).

RESULTS

Altogether 26 species belonging to 6 genera of mosquitoes *viz.*, *Aedes* (3 species), *Anopheles* (7), *Armigeres* (1), *Culex* (11), *Coquillettidia* (1) and *Mansonia* (3) were collected. Of these *Culex* species were most dominant, representing 76.6% of the total specimens collected followed by *Mansonia* (22%), *Anopheles* (1%), *Coquillettidia* (0.6%), *Armigeres* (0.3%) and *Aedes* (0.01%). The systematic list includes six species which are medically important in this region, *viz.*, *Cx. gelidus*, *Cx. quinquefasciatus*, *Cx. tritaeniorhynchus*, *Ma. annulifera*, *Ma. indiana* and *Ma. uniformis* were encountered in all the four type of collections employed (Table 1). Dusk collections contributed 89.1% of total collection, while ORC, IRC and ANLC contributed 6.1, 3.5 and 1.3% respectively (Table 2).

A total of 5943 mosquito specimens consisting of 17 species were collected in indoors by spending 640 man hours. *Cx. quinquefasciatus* was the most dominant species with 52% of total catch followed by *Ma. annulifera* 23.9%, *Ma. indiana* 7.7%, *Cx. tritaeniorhynchus* 6.8%, *Ma. uniformis* 3.7%, *An. subpictus* 3.2% and *Cx. gelidus* 1.8%.

Outdoor resting collections contributed 10289 specimens consisting 18 species of mosquitoes. *Cx. tritaeniorhynchus* was dominant (77.4%) followed by *Ma. uniformis* (11.4%), *Ma. indiana* (3.6%), *Cx. gelidus* (3.5%), *Cq. Crassipes* (1%) and *Ma. annulifera* (0.8%). The remaining species represented with less than 1%.

In dusk collections, the highest number (23) of species with 150692 mosquitoes were encountered. *Cx. tritaeniorhynchus* was the most dominant species (66.6%) followed by *Ma. uniformis* (10.7%), *Cx. gelidus* (10.6%), *Ma. indiana* (7.8%) and *Ma. annulifera* (3%). *Cx. quinquefasciatus* accounted for 0.1%.

A total of 2131 female mosquitoes consisting of 8 species were recorded in the ANLC. *Cx. quinquefasciatus* was the dominant species (44%) followed by *Ma. annulifera* (30.8%), *Ma. indiana* (9.6%), *Ma. uniformis* (7.6%), *Cx. tritaeniorhynchus* (5.9%) and *Cx. gelidus* (1.4%). *Armigerous subalbatus* and *Cx. fuscanus* were accounted for less than 1%.

TABLE 1. Mosquitoe species collected from Kuttanadu

Species	Indoor resting collection		Outdoor resting collection		Dusk collection		All night landing collection		Total	
	Nos.	%	Nos.	%	Nos.	%	Nos.	%	Nos.	%
Ae. (Stg) albopictus	2	0	7	0.1	2	0	0	0	11	0
Ae. (Stg) scutellaris #	0	0	1	0	0	0	0	0	1	0
Ae. (Adm) vexans vexans	0	0	12	0.1	0	0	0	0	12	0
An. (Ano) barbirostris	10	0.2	89	0.9	706	0.5	0	0	805	0.5
An. (Ano) pedetaeniatus	1	0	1	0	317	0.2	0	0	319	0.2
An. (Cel) jamesii	1	0	16	0.2	150	0.1	0	0	167	0.1
An. (Cel) pallidus	9	0.2	26	0.3	49	0	0	0	84	0
An. (Cel) subpictus	192	3.2	6	0.1	91	0.1	0	0	289	0.2
An. (Cel) tessellatus	0	0	0	0	8	0	0	0	8	0
An. (Cel) vagus	16	0.3	7	0.1	24	0	0	0	47	0
Ar. (Arm) subalbatus	2	0	43	0.4	457	0.3	10	0.5	512	0.3
Cq. crassipes	0	0	106	1.0	3	0	0	0	109	0.1
Cx. (Cux) bitaeniorhynchus	1	0	0	0	2	0	0	0	3	0
Cx. (Cux) fuscocephala	0	0	0	0	2	0	0	0	2	0
Cx. (Cux) gelidus	107	1.8	363	3.5	15980	10.6	30	1.4	16480	9.7
Cx. (Cux) infula	0	0	0	0	4	0	0	0	4	0
Cx. (Cux) pseudovishnui	1	0	0	0	5	0	0	0	6	0
Cx. (Cux) quinquefasciatus	3093	52.1	10	0.1	78	0.1	937	44.0	4118	2.5
Cx. (Cux) sitiens	0	0	0	0	1	0	0	0	1	0
Cx. (Cux) tritaeniorhynchus	404	6.8	7962	77.4	100325	66.6	126	5.9	108817	64.3
Cx. (Cux) vishnui	0	0	0	0	25	0	0	0	25	0
Cx. (Lop) sp. unidentified	0	0	3	0	0	0	0	0	3	0
Cx. (Lut) fuscanus	4	0.1	16	0.2	1	0	5	0.2	26	0
Ma. (Mnd) annulifera	1421	23.9	83	0.8	4529	3.0	656	30.8	6689	4.0
Ma. (Mad) indiana	458	7.7	369	3.6	11790	7.8	205	9.6	12822	7.6
Ma. (Mnd) uniformis	221	3.7	1168	11.4	16143	10.7	162	7.6	17694	10.5
Total	5943	100	10288	100	150692	100	2131	100	169054	100
%	3.5		6.1		89.1		1.3			100

Reared to adult (female) collected as larva from a discarded container.

TABLE 2. Average abundance of medically important mosquitoes

Species	Indoor resting collection (per man hour)	Outdoor resting collection (per man hour)	Dusk collection (per man hour)	All night landing collection (Human biting index)
Cx. (Cux) gelidus	0.2	0.7	19.5	0.1
Cx. (Cux) quinquefasciatus	4.8	0	0.1	2.9
Cx. (Cux) tritaeniorhynchus	0.6	14.3	122.6	0.4
Ma. (Mnd) annulifera	2.2	0.1	5.5	2.0
Ma. (Mnd) indiana	0.7	0.7	14.4	0.6
Ma. (Mnd) uniformis	0.3	2.1	19.7	0.5

DISCUSSION

Culex vishnui subgroup mosquitoes *viz.*, *Cx. pseudovishnui Cx. tritaeniorhychus* and *Cx. vishnui* are important vectors of JE. *Cx. tritaeniorhynchus* is extremely common and widespread. It has been incriminated as a major vector in India, Srilanka, Thailand, Sarawak and also in Japan and Taiwan (Reuben *et al.*, 1994). In Kuttanadu *Cx.tritaeniorhynchus* was the most abundant species representing more than 64% of the total mosquitoes, found 77.4% and 66.6% in ORC and DC. IRC accounted for 6.8% and ANLC for 5.9%. JE virus have been isolated from the wild caught *Cx.tritaeniorhynchus, Ma. indiana* and *Ma. uniformis* (Dhanda *et al.*, 1997) in Kuttanadu. The blood meal analysis of *Cx. tritaeniorhynchus* showed that 49% had fed on cow, 28% on both cow and goat (double feeding), 5% on pig and 1.4% on human (CRME, unpublished data).

Culex gelidus is a commonly distributed species, breeding in habitats like ground pools usually those containing much weeds, marshy tract etc. Barraud (1934). Isolation of JE virus have been made from this species, 5 from Cuddalore, Tamil Nadu (Gajanana *et al.*, 1997) and 3 from Mandya, Karnataka (Mourya *et al.*, 1989). *Cx. gelidus* preferred mainly animals for feeding: cow (36%), pig (12%) and human (6%), (CRME unpublished data).

Culex quinquefasciatus is a primary vector of urban filariasis caused by periodic *Wuchereria bancrofti*. Chickunguniya and Eastern equine encephalitis viruses have also been isolated from *Cx. quinquefasciatus* in Thailand. Laboratory transmission of JE virus has been demonstrated in North America (Bram, 1967). *Cx. quinquefasciatus* is capable of transmitting JE virus experimentally (Banerjee *et al.*, 1977). Isolation of JE virus has been made from *Cx. quinquefasciatus* in Karnataka, India (Mourya *et al.*, 1989). Few isolations of JE virus have been made from several countries including India and Vietnam but the species is regarded as a poor vector and not of importance in the natural cycle of disease (Sirivanakarn, 1976). Feeding pattern of *Cx. quinquefasciatus* was found to be anthropophilic in nature since human feedings accounted for 75% in Kuttanadu (CRME, unpublished data).

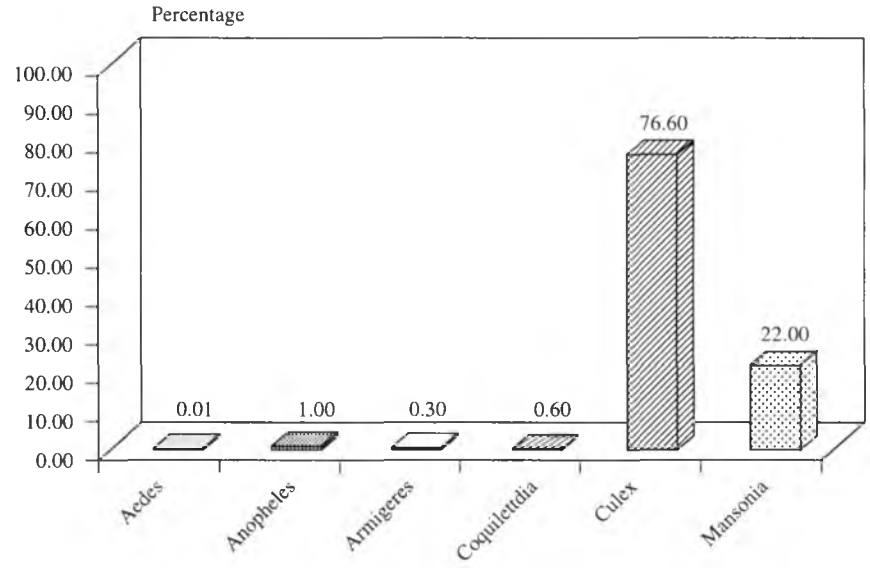

FIGURE 2. Genus-wise abundance of mosquitoes.

Members of the subgenera *Mansonioides* and species of *coquillettidia* have been implicated in the epidemiology of several arboviruses in Africa (Theiteral and Downs, 1973). In Kuttanadu *Cq. crassipes* was collected mainly from vegetation. The species of *Mansonia* namely *Ma. annulifera, Ma. indiana* and *Ma. uniformis* have been incriminated as vectors of Brugian filariasis in Travancore, Kerala (Iyengar, 1938). In India, Brugian filariasis has a localised distribution restricted to rural areas in Andhra Pradesh, Assam, Kerala, Madhya Pradesh, Orissa, Tamil Nadu and West Bengal (WHO, 1994). These species also have been implicated in the epidemiology of JE, for example, *Ma. annulifera* in Assam (Chakravarty *et al.*, 1981), *Ma. uniformis* in Karnataka (Mourya *et al.*, 1989) and all these three species of *Mansonia* in Kerala (Dhanda *et al.*, 1997). Vertical transmission of JE virus was reported in *Ma. indiana* and *Ma. uniformis* (Arunachalam *et al.*, 2002).

Though JE virus has been isolated from the species like *Anopheles barbirostris*, *An. peditaeniatus*, *An. subpictus*, *Culex bitaeniorhynchus*, *Cx. fuscocephala* and *Cx. infula* from elsewhere in India, JE virus was not detected/isolated from these species in Kuttanadu area except *An. subpictus* from which a single isolation was made during the JE outbreak in 1996 (Dhanda *et al.*, 1997).

Epidemiological patterns of disease transmission vary in different parts because of the differences in climate, vector abundance and vector behaviour. Vector abundance and vector behaviour are some of the most important parameters that have to be considered while implicating a mosquito species as a vector. The results shows that those six species having medical importance in this region *viz.*, *Cx. gelidus*,

Cx. quinquefasciatus, *Cx. tritaeniorhynchus*, *Ma. annulifera*, *Ma. indiana* and *Ma. uniformis* were observed comparatively in higher densities atleast in any one type of collection. In indoor resting collections, higher densities of anthropoplic mosquitoes, *Cx. quinquefasciatus* and *Ma. annulifera*, which are the known vectors of *Wuchereria bancrofti* and *Brugia malayi* infections are recorded. In dusk collection higher densities of the zoophilic mosquitoes, the primary vector of JE, *Cx. tritaeniorhynchus* followed by *Ma. uniformis*, *Cx. gelidus*, *Ma. indiana*, which are considered to be the secondary vectors of JE in this region, are recorded. The rest of the species are considered to be of no medical importance in Kuttanadu region because of their low abundance, though some of the species are suspected and/or proven vectors elsewhere.

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Effect of habitat manipulation on population density of odonates in paddy ecosystem

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ABSTRACT: Trials were conducted in a Paddy field to study the effect of habitat manipulation on the population density of odonates. The field was divided into direct sown and transplanted paddy and each was further subdivided into weeded and unweeded plots. Population of both damselfly and dragonfly naiads were counted in one m^2 in each plot. Results revealed that the direct sown paddy plot harboured more damselfly population than transplanted paddy plot while the dragonfly population was high in transplanted plot than in direct sown plot. Odonate population increased gradually with monsoon and declined during dry weather.

KEYWORDS: Habitat manipulation, population density, odonates.

INTRODUCTION

Odonates are major predatory insects present in the paddy ecosystem. Prasad (1989) and Kumar and Roy (1994) studied the seasonal fluctuation and population density of some odonates. Seasonal abundance and species diversity of zygopteran naiad in fish farming pond was studied by Kumar (1995). Painter (1998) reported that sites with little shading from vegetation were favoured by territorial males and ovipositing females. The present study was undertaken to examine the effect of habitat manipulation on population density and seasonal distribution of odonates in the paddy ecosystem.

MATERIALS AND METHODS

Two field trials were conducted in the Annamalai University Farm premises.

Trial I (Aug. 2000 to Jan. 2001)

A plot of ten cents was divided into two sub-plots, one was with direct sown paddy, another with transplanted paddy. The age and variety (CO-43) of crop was same

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in both plots. Both were sown on 20 August 2000 and transplanting was done on 29 September 2000 in the latter case. Again these two plots were sub-divided into weeded and unweeded plots. Weeded plots were kept weed free as and when weeds appeared. The common weeds noticed were *Cyanodon dactylon, Cyprus rotendus*, *C. deformis*, *Cenchrus setigerus*, *Echinochloa crusgalli*, *E. colonum* and *Amaranthus sp.*

Trial II

The same trial was repeated as Trial II from Jan. to May 2001. Sowing was taken up on 25th January and transplanting was done on 2 March, 2001. In the paddy field stagnant water condition was maintained throughout the study period to encourage the development of odonates which indicated the population level in wetland ecosystem. Both trials were conducted in different locations, but adjacent to other paddy fields.

A tinsheet box without top and bottom of one m^2 with 15 cm height was made, and used for counting of naiads in paddy field. The box was placed in the field in such a way (by slightly inserting into the mud) that there is no escape of naiads held within the box. The box was kept in three different places randomly in the respective plots [Direct sown weeded and unweeded; Transplanted weeded and unweeded (4×3)] and the number of zygopteran and anisopteran naiads were counted and recorded in both the trials. Observations were taken in both transplanted and direct sown crop, only after transplanting. The data were subjected to factorial CRD and ranked using DMRT.

RESULTS

Trial I (Aug. 2000 to Jan. 2001)

In direct sown weeded plot the damselfly population ranged from 13.83 to 43.50 whereas the dragonfly population varied from 11.16 to 25.78. The damselfly and dragonfly population in the unweeded plot ranged from 28.50 to 53.16 and 6.66 to 22.83, respectively [Fig. 1(a)]. In transplanted weeded plot the damselfly population ranged from 7.50 to 22.49 and dragonfly ranged from 20.83 to 37.16 and the same in unweeded plot ranged from 14.83 to 25.83 and 10.00 to 25.03 respectively [Fig. 1(b)].

The mean population of damselfly in direct sown weeded plot was 24.22, whereas in transplanted weeded plot it was 11.98. The same in both direct sown and transplanted unweeded plot was 39.36 and 18.99 respectively. The mean population of dragonfly in direct sown weeded plot was 16.75 and in transplanted weeded plot it was 29.17, whereas in both direct sown and transplanted unweeded plot the same was 11.57 and 16.38 respectively.

Trial II (Jan. 2001 to May 2001)

The recorded data revealed that in direct sown weeded plot the damselfly population ranged from 0.75 to 13.99, whereas the dragonfly population varied from 0.50 to 3.86. The damselfly and dragonfly population in the unweeded plot ranged from 1.70 to 23.86 and 0.50 to 0.76, respectively (Fig. 2a). In transplanted weeded plot, the

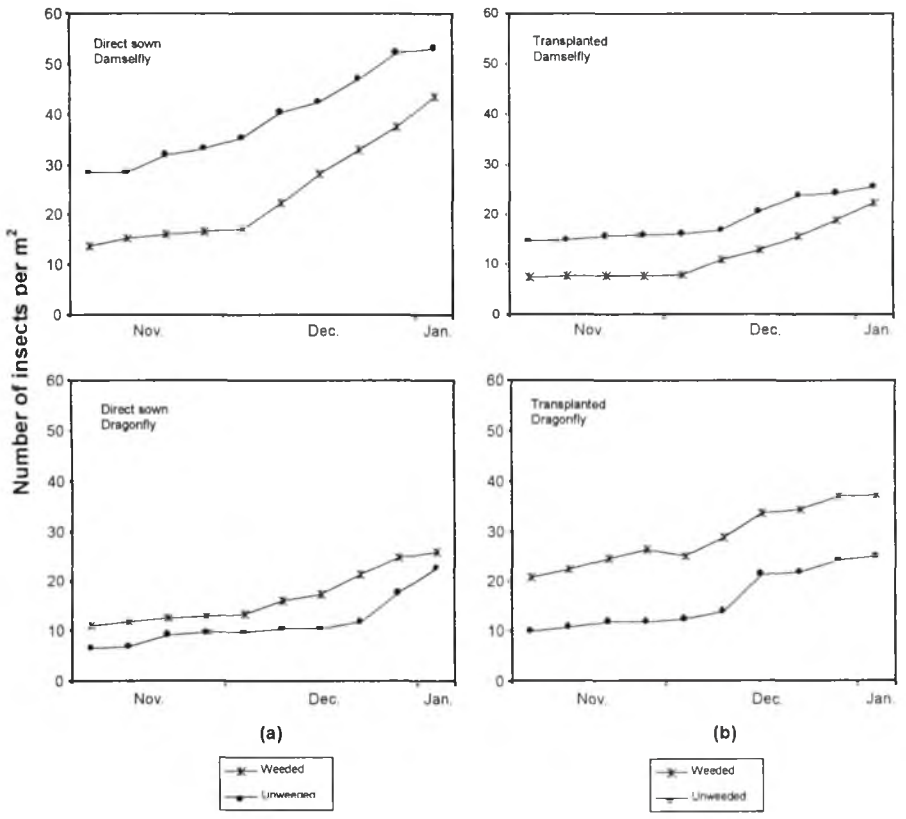

FIGURE 1. Effect of habitat manipulation Trail I (Aug 2000 to Jan 2001).

damselfly population ranged from 0.50 to 5.12 and dragonfly ranged from 0.82 to 11.06. The damselfly and dragonfly population in unweeded plot ranged from 1.03 to 12.19 and 0.50 to 4.59, respectively (Fig. 2b).

The mean population of damselfly in direct sown weeded plot was 7.71, whereas in transplanted weeded plot it was 1.97. The same in both direct sown and transplanted unweeded plot was 13.26 and 7.82, respectively. The mean population of dragonfly both in direct sown and transplanted weeded plot was 2.04 and 6.23, respectively whereas the same in direct sown unweeded plot was 0.62 and in transplanted unweeded plot, it was 2.14.

DISCUSSION

Trial I

The recorded data showed that during first week of November, the population was low and during first week of January it was high. Generally, whether it was direct sown or

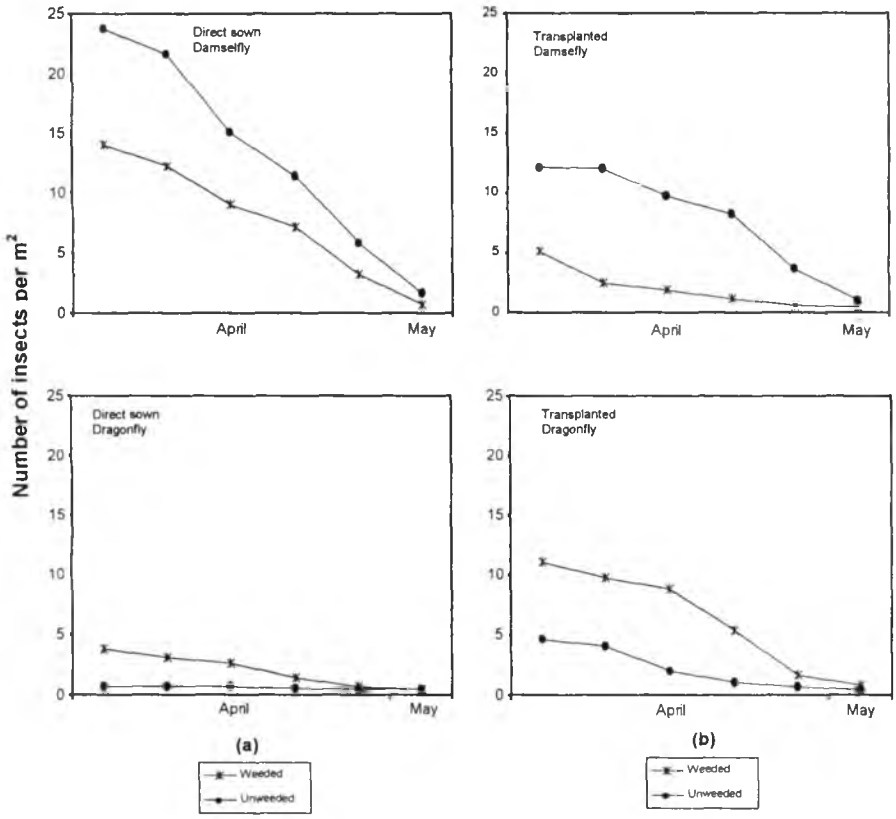

FIGURE 2. Effect of habitat manipulation Trail II (Jan 2001 to May 2001).

transplanted paddy, damselfly or dragonfly, population was less during first week of November and high in first week of January.

The possible reason for the high population in January may be due to favourable weather factors like rainfall, low temperature and high RH during the months of November and December during which Odonate population slowly increased and reached its peak in January. This observation of less population before monsoon and more after monsoon was in accordance with the earlier observations made by Prasad (1989). Hence monsoon and other weather factors play a vital role in determining the population dynamics of odonates.

Trial II

The data revealed that during third week of March Odonate population was maximum and it was minimum during first week of May. The reason for high population during March may be again due to weather factors like temperature and RH. Rainfall in

the month of December and January also influenced the population and thereafter declined gradually from March to May. At the end of May the population of both Odonates was almost nil, because from March onwards the temperature gradually increased and it was high in May and there was no rainfall recorded also. Temperature is an important factor determining the Odonate population (Miller, 1987). Hence when temperature increased, the naiads population of both damselflies and dragonflies decreased. Also the population of Odonates was less when the paddy crop attained maturity, because before harvest, they have the tendency to emerge as adults. So within the crop period, it completes its life cycle. According to climatic situation, some Odonates have synchronization of emergence (Corbet, 1980). Fraser (1934) also reported that Odonate's emergence appear to coincide with the draining of paddy-lands prior to harvest. Hence, it is clear that before harvest, the population level decreased due to their synchronized emergence with crop maturity.

Irrespective of the seasons, the high population of damselfly, in unweeded plot may be due to the ovipositional preference. As they are endophytic, they prefer to lay eggs on plant tissues (Miller, 1987). Hence, the population of damselfly was higher in unweeded paddy plot where the plant canopy was more rather than weeded plot.

The reasons for the high population of dragonfly in weeded plot, may be due to their exophytic nature, where in they lay (sprinkle) their eggs on the surface of water while on wings. Miller (1987) also reported that before laying eggs, dragonflies hover the water surface repeatedly, and lay clusters of eggs on water. Normally the weeded plot has low plant canopy when compared to unweeded, so the low plant population allows the dragonfly to hover the water surface and lay eggs easily, whereas in the unweeded plot it is not so. Hence the dragonfly population was higher in weeded plot and lower in unweeded plot.

The population of damselfly was high in direct sown weeded plot than in the transplanted weeded plot, and the possible reasons may be again the higher plant canopy in direct sown than in transplanted paddy. The population of dragonfly was more in transplanted weeded plot than in direct sown weeded plot as transplanted weeded plot had lesser plant canopy than in direct sown weeded plot which facilitated dragonfly oviposition.

In summary, the dragonfly preferred habitats with lesser plant canopy and the damselfly preferred habitats with higher plant canopy, irrespective of whether it is direct sown or transplanted paddy. In first trial (August 2000–January 2001) which coincided with monsoon, the population of odonates were much higher whereas in second trial (Jan. to May, 2001) which experienced high temperature and very less rainfall the same was much lesser.

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Feeding potential of spiders (Order: Araneae) on *Aphis craccivora* Koch occurring on Cotton

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ABSTRACT: A laboratory study was carried with 14 species of spiders occurring in a cotton field in North Gujarat to evaluate their feeding potential on *Aphis craccivora* on cotton. The feeding efficiency varied with life stage and sex of the spiders. Adult females consumed more number of preys than adult males and subadult stages. Among the 14 species tested, *Lycosa poonaensis* and *L. tista* consumed the highest number of prey and *Oxyopes chitrae* and *Phidippus pateli* consumed the least number of preys.

KEYWORDS: Spider, *Aphis craccivora*, feeding potential, cotton

Despite of dearth of supporting quantitative evidence, many arachnologists and entomologists have tacitly assumed the importance of spiders in regulating insect population. Spiders are highly abundant in agricultural fields and if conserved or augmented, they can regulate many insect pests. As a group, they are highly resilient in agroecosystems, long lived and readily seek out new fields after harvest. They feed almost exculsively on insects, but little attention has been paid to their use in insect pest suppression. Bishop and Blood (1981) estimated the importance of spiders in preventing crop loss by relating the abundance of spiders feeding on *Heliothis* sp., to fruit damage levels in an unsprayed cotton field in southeastern Queensland, Australia. They concluded that the damage threshold was frequently exceeded despite predation by spiders and their predatory role must be supplemented to ensure economic yields. The suppression of major cotton pests such as aphids, bollworms and spider mites by spiders was observed by Li and Jiang (1981) in Nanyang region, China. In another study, Yamanaka *et al.* (1973) found that the presence of linyphids in experimental plots resulted in significantly less leaf damage by the tobacco cut worm, *Spodoptera* sp. than was observed in plots from where spiders were removed. Mansour *et al.* (1980) found that the larval populations of the apple pest *Spodoptera littoralis* did not develop to damaging proportions on the trees occupied by spiders, whereas significant

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damage was observed on trees from where spiders were removed. The predatory role of spiders in the control of maize stalk borer, *Chilo partellus* (Singh *et al.*, 1975), tobacco caterpillar, *S. litura* (Sitaramaiah *et al.*, 1980) and of coconut leaf eating caterpillar *Opisina arenosella* (Sathiamma *et al.*, 1987) have been recognized. Numerous investigations indicate specific spider species as important predators of arthropod pests at least in the laboratory. The objective of the present study was to evaluate the feeding potential of dominant spiders associated with aphids on cotton fields, in the laboratory conditions.

Spiders were collected from cotton fields of North Gujarat region (21° 58′–24° 30′ N, 71° 16′–73° 25′ E) of India. Field collected and laboratory reared 3rd and 4th instar spiderlings, sub adult and adult males and females of 14 dominant spiders were used to study the feeding potential. The studies were carried out at 25–30 °C. The relative humidity was maintained at 60–80% throughout the period by keeping moistened wad of cotton in the jar. A definite number of aphids, *Aphis craccivora* Koch was placed on twigs of cotton plants with 2–4 leaves, covered with bell jars. The cut end of the twig was kept immersed in a beaker containing water. The test spiders were starved for 24 hr prior to the experiment and were placed individually on cotton twigs. The addition of prey was made at such a frequency that the prey density remained constant throughout the trial. Nymph stages of aphids were used as prey to study predation. Preys consumed or killed by spiders were counted at every 6 hr interval for three days for each trial. The 14 dominant spiders selected for the study were *Amaurobius shantiae* Patel an Patel, *Cheiracanthium melanostoma* (Thorell), *Clubiona pashabhaii* Patel and Patel, *Lycosa poonaensis* Tikader, *L. tista* Tikader, *Oxyopes chitrae* Tikader, *O. shweta* Tikader, *Pardosa birmanica* Simon, *P. sumatrana* (Thorell), *Phidippus pateli* Tikader, *Plexippus paykullii* (Audouin), *Theridion manjithar* Tikader, *Thomisus pugilis* Stoliczka and *Xysticus sujatai* Tikader 3rd and 4th instar stages, sub adult and adult males and females were only taken to assess the feeding capacity of spiders in the laboratory.

The spiders were found to prey upon all the life stages of aphids available within its reach. Table 1 shows the feeding capacity of the 14 species of spiders on the nymphs of aphids. All the test species were found to prey on aphids. The rate of predation was found varying among different species of spiders and between sexes. Females of all spiders consumed more number of preys than males. At the 3rd instar stage of the test spider species, the rate of predation varied from 0.4–18.5 nymphs of aphids in 24 hr. *Lycosa poonaensis*, *Pardosa birmanica*, *P. sumatrana*, *L. tista* and *Amaurobius shantiae* recorded a high rate of predation (14.4 to 18.5 nymphs per 24 hr). *Xysticus sujatai* consumed only 0.4 nymphs in 24 hr and occupied the last rank in predation. At the 4th instar stage, the rate of predation varied from 2.0–28.2 nymphs in 24 hr. *L. poonaensis*, *L. tista*, *P. birmanica*, *A. shantiae*, *T. pugilis* and *P. sumatrana* recorded a high rate of predation (19.5 to 28.2 nymphs per 24 hr). *Oxyopes chitrae* consumed only 2.0 nymphs in 24 hr and occupied the last rank. The same tendency was observed with sub adult male and female as in the case of 3rd and 4th instar spiderlings. The adult females of *L. poonaensis*, *L. tista*, *P. birmanica*, *P. sumatrana*, *A. shantiae*, and

TABLE 1. Feeding potential of dominant spiders on *Aphis craccivora* occurring on cotton, in the laboratory

Spider species and family	No. of aphids eaten during 24 hr (mean of 10 replicates)								
	3rd instar	4th instar	Sub adult male	Sub adult female	Adult male	Adult female	Mean ± S.D	Feeding Rank	C.V. (in%)
Amaurobius shantiae (Amaurobidae)	14.4	21.0	28.2	36.2	18.8	43.6	27.03 ± 10.19	5	37.70
Cheiracanthium melanostoma (Clubionidae)	02.8	05.6	08.1	09.1	06.6	10.5	07.11 ± 02.49	10	35.12
Clubiona pashabhaii (Clubionidae)	03.4	08.6	05.6	12.6	07.6	18.4	09.36 ± 04.92	8	52.56
Lycosa poonaensis (Lycosidae)	18.5	28.2	38.6	39.5	24.0	51.5	33.80 ± 11.03	1	33.05
Lycosa tista (Lycosidae)	14.6	22.7	36.2	33.2	36.0	48.5	31.86 ± 10.76	2	33.80
Oxyopes chitrae (Oxyopidae)	01.9	02.0	02.2	02.4	02.1	02.5	02.18 ± 00.20	13	09.60
Oxyopes shweta (Oxyopidae)	02.2	03.4	04.2	04.7	03.4	05.4	03.88 ± 01.02	12	26.53
Pardosa birmanica (Lycosidae)	17.2	21.2	31.0	38.6	21.2	48.2	29.56 ± 09.86	3	33.35
Pardosa sumatrana (Lycosidae)	16.3	19.5	36.7	29.7	22.5	43.7	28.06 ± 09.67	4	34.54
Phidippus pateli (Salticidae)	03.3	04.1	01.3	01.1	00.4	00.6	01.80 ± 01.39	14	77.37
Plexippus paykullii (Salticidae)	04.4	08.2	08.1	08.6	10.2	12.4	08.65 ± 02.41	9	27.93
Theridion manjithar (Theridiidae)	03.2	03.5	04.5	05.1	04.4	05.7	04.40 ± 00.95	11	37.70
Thomisus pugilis (Thomisidae)	13.6	19.8	21.4	28.2	23.0	31.6	22.93 ± 05.78	6	25.22
Xysticus sujatai (Thomisidae)	00.4	06.8	13.4	14.4	08.6	21.4	10.83 ± 06.59	7	60.86

T. pugilis consumed 31.6 to 51.5 nymphs in 24 hr whereas their male counterparts consumed 18.8 to 36.0 nymphs in 24 hr.

The data presented in Table 1 revealed that the feeding rate varied with different life stages in different spiders. *P. pateli* showed maximum variation and the coefficient of variation was 77.37%. Different life stages of *O. chitrae* showed minimum variation and the c.v. value was 9.6%. The two wolf spiders, *L. tista* and *L. poonaensis* consumed maximum number of preys in 24 hr and the jumping spider, *P. pateli* consumed minimum number of preys.

One of the most frequently analysed problems is the effect of prey and predator density during the course of predation. They also feed freely on beneficial insects (Whitcomb and Bell, 1964). On one hand the spiders serve as much needed insect predators and on the other hand, they constantly compete with insect predators.

Spiders are known to achieve phenomenal densities in natural situation and to consume large quantities of insect pests.

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Quantitative changes in total body proteins and haemolymph proteins due to azadirachtin in the larva of *Corcyra cephalonica* (ST.)

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ABSTRACT: Azadirachtin supplied through diet caused a decrease in the total body proteins as well as haemolymph proteins of *Corcyra cephalonica* larvae.

KEYWORDS: Azadirachtin, *Corcyra cephalonica* (St.), proteins.

The adverse effects of synthetic insecticides are very widely recognised and botanical pesticides are being considered as safer substitutes and they are being subjected to detailed studies. In this context, the effect of the active principle of neem extract, azadirachtin, on proteins in the last instar larva of *Corcyra* was studied. Proteins act as essential component of structural material and are in a state of continuous flux with regard to their synthesis and degradation.

Corcyra cephalonica was reared in the laboratory at 26 ± 1 °C and 93.5% relative humidity (Theotia and Singh, 1975). Freshly hatched larvae of *C. cephalonica* were kept in rearing glass chamber for 15 days on a diet medium comprising of coarsely ground jowar mixed 10% w/w ground nut powder and 5% w/w yeast.

The normal dietary medium was mixed with three different concentrations of neem extract containing azadirachtin as 10, 15 and 20% v/w and offered to the test insect as food. In each container 100 larvae were allowed to feed. A control set was maintained simultaneously. The larvae were taken out after 24, 48, and 72 hr of treatment.

Haemolymph was obtained by making a small puncture by means of sharp needle at the dorsolateral side of the prothoracic segment and the fluid was collected into a fine glass capillary tube.

For water soluble body protein estimation, five larvae from each set were taken. The larvae were homoginized in two ml of ice cold distilled water. The homogenate was centrifuged in a refrigerated centrifuge at 3000 rpm for 5 min. Proteins in the above

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TABLE 1. Effect of azadirachtin treatment on total and haemolymph proteins in last instar larva of *C. cephalonica*

Hours after Treatment	Concentration of protein (mg/g body wt			
	Normal	10% azadirachtin	15% azadirachtin	20% azadirachtin
Body protein (mg/g)				
0.00	1.79±0.02	1.88±0.02	1.85±0.05	1.78±0.20
24	1.72±0.3	1.74±0.5	1.59±0.15	1.31±0.03
48	1.40±0.05	1.3±0.4	1.22±0.04	1.12±0.01
72	2.71±0.04	0.90*±0.01	0.70±0.04	0.70*±0.04
Mean	1.91	1.46	1.34	1.226
% of change of protein over normal		31.23	42.50	55.86
Haemolymph Protein (mg/g)				
0.00	1.00±0.08	0.98±0.06	0.98±0.05	0.95±0.03
24	1.71±0.09	1.71±0.05	1.40±0.08	0.60±0.057*
48	2.50±0.32	2.40±0.07	2.0±0.02	0.40±0.05*
72	3.60±0.62	0.95±0.04*	0.90±0.054*	0.80±0.06*
Mean	2.2	1.51	1.32	0.6875
% of change of protein over normal		45.69	66.66	220

$P^* = 0.05$ values represent mean and SD of 4 replicates.

samples were estimated by the method of Lowry *et al.* (1951) using bovine serum albumin as standard.

Total body proteins of treated larvae showed a decrease at 24 and 48 hr of treatment (Table 1). But at 72 hr there was rise in the protein content of the normal larvae. There was significant decrease in the proteins of treated larvae at 72 hr even at lower concentrations of azadirachtin.

Haemolymph proteins showed increase with increasing age. There was significant decrease of proteins in azadirachtin treated larvae at higher concentrations at 24, 48 and 72 hr of treatment. At lower concentrations of azadirachtin the decrease in haemolymph proteins was significant only at 72 hr of treatment.

Estimation of total body proteins showed that it increased progressively with increased age of larva. But in case of azadirachtin treated larva there was decrease in the body protein. This decrease was much more at 72 hr of treatment, i.e. 49.4% decrease. Similar results were obtained with annona treated red cotton bug (Bhagawan *et al.*, 1992).

Haemolymph protein analysis also showed similar trend. Similar reduction in haemolymph protein was reported after azadirachtin treatment in *Periplanata americana* (Quadri and Ahmed, 1978).

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Concomitant effect of *Bacillus thuringiensis* H-14 toxin and Atropine sulphate on the gut epithelial cells of female *Aedes aegypti* mosquitoes

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ABSTRACT: Female *Aedes aegypti* mosquitoes were fed with *Bacillus thuringiensis* toxin along with atropine sulphate to study their concomitant effect. It was observed that atropine sulphate with toxin showed perturbations in the cellular structure as atropine sulphate helped in reduction of peristaltic movements which probably resulted in more binding of toxin to the epithelial cells of midgut, thus causing more tissue destruction.

KEYWORDS: *Aedes aegypti*, *Bacillus thuringiensis*, H-14 toxins

Bacillus thuringiensis toxins get bound to the gut epithelial cells, which lead to disruption of gut integrity and finally death of the larva due to starvation or septicemia (Knowles and Dows, 1993).

Most of the studies on *B. thuringiensis* toxin are oriented towards its effect on the larvae and the detailed toxicity mechanism in adult mosquitoes is lacking. Recently, it has been shown that incorporation of toxin in the adult blood meal caused hyper-peristaltic movement in the gut as a result of which mosquitoes defecate ingested blood within 15–30 min. Incorporation of atropine sulphate reduce involuntary muscle movements and caused significantly higher mortality (Mourya *et al.*, 2001).

The concomitant effect of toxin and atropine sulphate on *Aedes aegypti* adult at cellular levels in the midgut of mosquitoes was studied.

Mosquitoes used for the experiments were from a laboratory colony of *A. aegypti* maintained at Microbial Containment Complex B. J. Medical College, Pune. *VectoBac 12AS aqueous formulation*: obtained from Hoechst Schering AgrEvo Ltd. was used as toxin source. *Atropine sulphate* from Sigma Chemical Co. USA (A-0257) was

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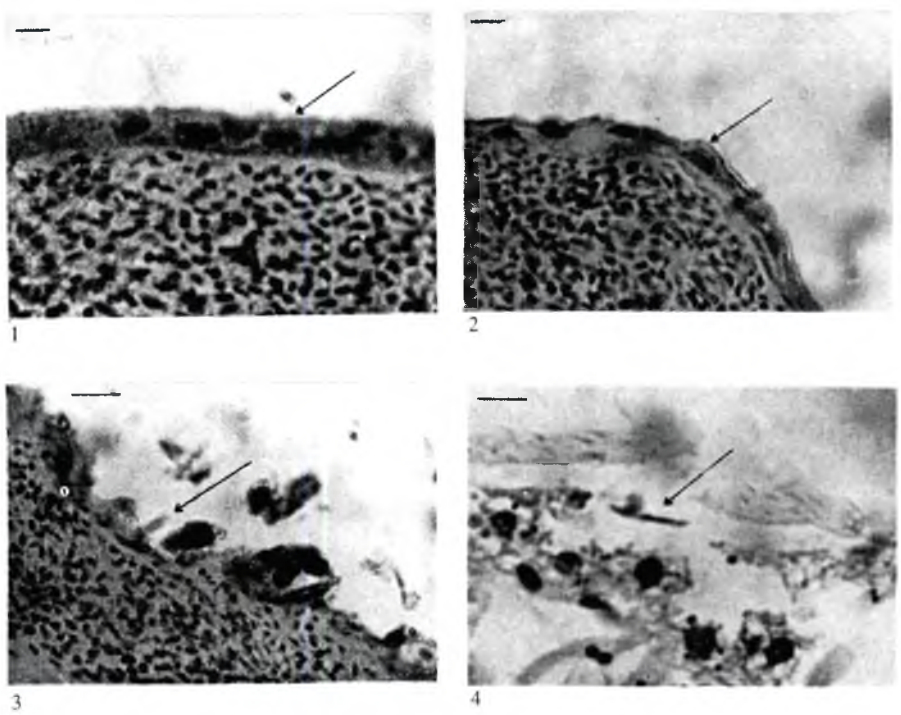

Transfer sections of midgut epithelial cells of female *A. aegypti* mosquitoes, [Bar = 0.01 mm; Arrow = Epithelial cells]:

FIGURE 1. Fed on normal blood (control).
FIGURE 2. Fed on mixture of blood and atropine sulphate (50 mg/l) (control).
FIGURE 3. Fed on mixture of blood and toxin.
FIGURE 4. Fed on mixture of blood, toxin and atropine sulphate (50 mg/l).

used for the experiments. Four-to-five day old female mosquitoes were fed on 2% mixture of VectoBac [commerical product] in fresh defibrinated chicken blood, using parafilm as an artifical membrane (Harada *et al.*, 1996). Similary another batch was fed on the toxin along with 50 mg/l concentration of atropine. The approximate does of the toxin in the blood was 24 ITU/ul. Almost 90% of the females fed on the bloodmeal-containing toxin defecated ingested blood within 15 to 30 min after feeding as observed earlier (Mourya *et al.*, 2001). After 8 hrs of feeding the midguts were dissected out in normal saline and fixed in neutral formalin. The microscopic evaluation of change in the morphology of midgut tissues was done on formalin fixed, paraffin embedded tissues stained by Haematoxiline and Eocine staine.

On microscopic examination it was found that there was perturbation in the continuity of epithelial cells. Damage of protein skeleton of the cells, which maintain

cell structure and shape, was more in case of combination of VectoBac and atropine sulphate (Fig. 4) as compared to the controls, which were fed, on blood or blood and atropine sulphate (Figs 1 to 3). A similar observation on cellular damages by toxins of cyanobacteria on the midgut epithelial cells of *A. aegypti* was made by Saario *et al.* (1994). Atropine sulphate along with defibrinated blood did not show any lesion in the cell wall structure of epithelial cell (Fig. 2). This suggests that muscle relaxation effect of atropine sulphate might have affected the gut peristaltic movements and mosquitoes did not excrete the ingested blood-containing toxin.

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Effect of pesticides on *Amblyseius longispinosus* (Evans), a predator of Red Spider mite *Tetranychus ludeni* Zacher

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ABSTRACT: The effect of pesticides on the predatory mite, *Amblyseius longispinosus* (Evans) assessed through dry film technique revealed that all the chemical pesticides tested *viz.*, triazophos 0.05%, dicofol 0.05%, quinalphos 0.05% and malathion 0.05% were highly toxic to the predator. Among the botanical pesticides tested, the leaf extract of *Hyptis suaveolens* 10% showed highest mortality. The mortality of the predator in the botanical pesticides tested ranged from 27.22 to 47.63%, 48 hours after treatment.

KEYWORDS: Predatory mite, pesticide toxicity, *Amblyseius longispinosus*

It is an established fact that the most important factor which prevents plant feeding mites from gaining overwhelming dominance is the activity of their natural enemies. Phytoseiid mites have been recognized as one of the valuable groups among the predators of phytophagous mites (McMurtry *et al.*, 1970). The phytoseiid mite, *Amblyseius longispinosus* (Evans), commonly encountered in the colonies of the red spider mite, *Tetranychus ludeni* infesting beans was reported as a promising predator of the mite (Mallik, 1974). One of the reasons attributed to the mounting mite problems in vegetables is the destruction of the predatory mites due to indiscriminate use of pesticides. In this context, the present study to assess the effect of currently used chemical and botanical pesticides on *A. longispinosus* was undertaken. The effect of the entomopathogenic fungus, *Fusarium pallidoroseum* Koch, the biocontrol agent currently used for management of cowpea aphids, was also evaluated against the predator.

The experiment was conducted in CRD with ten treatments and five replications at College of Agriculture, Vellayani during August 2000. Details of insecticides/botanical pesticides evaluated are presented in Table 1. Emulsified extracts of botanical pesticides used in the study were prepared by adding 5 g of bar soap into one litre extract of each biopesticide at the respective concentrations. The chemical

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TABLE 1. Toxicity of pesticides to the predatory mite *Amblyseius longispinosus*

Treatment	Percentage mortality at		
	6 h	24 h	48 h
Malathion (0.05%)	60.84 (7.86)	100 (10)	100 (10)
Quinalphos (0.03%)	57.21 (7.62)	100 (10)	100 (10)
Dicofol (0.05%)	79.77 (8.98)	100 (10)	100 (10)
Triazophos (0.05%)	100 (10)	100 (10)	100 (10)
Garlic emulsion (2%)	26.50 (5.24)	37.71 (6.22)	37.71 (6.22)
Neem oil emulsion (5%)	42.30 (6.58)	42.30 (6.58)	42.30 (6.58)
Neem garlic emulsion (2%)	40.02 (6.4)	41.58 (6.52)	41.58 (6.52)
Emulsified extract of *Andrographis paniculata* 10%	10.63 (3.41)	28.83 (5.46)	38.73 (6.30)
Emulsified extract of *Hyptis suaveolens* 10%	14.22 (3.90)	40.42 (6.43)	47.63 (6.97)
Fish oil insecticidal Soap (2.5%)	16.3 (4.15)	27.22 (5.31)	27.22 (5.31)
Fusarium pallidoroseum @ 7×10^6 spores/ml	7.28 (2.87)	6.10 (2.66)	6.10 (2.66)
CD (0.05)	1.81	1.46	1.44

Figures in parentheses are transformed using $\sqrt{x+1}$.

pesticides were diluted with water to get required concentration of the spray solutions. The spore suspension of the entomopathogenic fungus, *F. pallidoroseum*, infecting cowpea aphids was prepared from eight-day-old culture and spore suspension standardized to get 7×10^6 spores/ml. Fish oil insecticidal soap was first dissolved in luke warm water prior to preparation of spray solution at the specified concentration.

Dry films of the pesticides at the test concentrations were made by swirling 2 ml each of the test solutions and then shade drying for an hour. In addition, cowpea leaf dipped in test solution was shade dried and placed inside the petridish. Six adult predators of *A. longispinosus* were released into each petridish and the petridishes sealed using a klin film. Mortality of the predator was recorded 6, 24 and 48 h after release of the predators in the different treatments. Mortality in the treatments was

adjusted for control morality using Abbot's formula (Abbot, 1925) and the data were subjected to analysis of variance.

In the observations recorded six hours after the exposure of *A. longispinosus* to the recommended dose of pesticides, 7.28 to 100 per cent mortality was seen in different treatments (Table 1). Cent percent mortality of the predator was observed in triazophos 0.05%. This was followed by dicofol, quinalphos and malathion with mean values of 79.77, 60.84, and 57.21, respectively. While studying the effects of the pesticides on *A. tetranychivorous*, Jagdish and Channa Basavanna (1989) found that dicofol, quinalphos, carbaryl and malathion caused 93.89 to 100 per cent of the mortality of the predator twelve hours after treatment at the recommended dose.

Among the botanical pesticides evaluated, neem oil emulsion 5% showed the highest mortality (42.30) after six hours (Table 1). An increase in mortality of the predatory mites was observed in the botanicals in the subsequent observations taken 24 and 48 h after treatment. However, the mortality was much less than that in synthetic insecticides and the maximum mortality was only 47.63 per cent, noted in *Hyptis suaveolens* at 48 h after exposure. There is a general contention that botanicals are safe to natural enemies. The present studies have shown that the botanicals are safe, only when compared to chemical pesticides. The results also indicated that the negative effect of botanicals on the natural enemy cannot be overlooked. The mortality of the predators in *F. pallidoroseum* was significantly lower than in the rest of the treatments. Earlier reports by (Mathai *et al.*, 1999) indicated that *F. pallidoroseum* is safe to natural enemies.

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Galleria mellonella L. (Lepidoptera: Galleridae) as a new host for *Goniozus nephantidis* Mues. (Hymenoptera: Bethylidae)

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ABSTRACT: Screening of 23 species of lepidopteran caterpillars for parasitization by *Goniozus nephantidis* in the laboratory revealed successful parasitization and development by the parasitoid on larvae of the greater wax moth, *Galleria mellonella*. Although oviposition was noticed on larvae of *Herculia nigrivita* and *Sylepta derogata*, they did not support the development of the parasitoid. Laboratory studies on various biological parameters of *G. nephantidis* on *G. mellonella* revealed that the number of eggs laid/host larva, number of adults emerged, total developmental period and sex ratio of progeny did not show any significant difference with other two known hosts, *viz.*, *Opisina arenosella* and *Corcyra cephalonica*. *G. mellonella*, the newly discovered alternative host of *G. nephantidis* can be used for mass rearing of the parasitoid in the laboratory.

KEYWORDS: *Opisina arenosella*, *Goniozus nephantidis*, *Galleria mellonella*, parasitoid, alternative host

Goniozus nephantidis Mues. (Hymenoptera: Bethylidae) is one of the most important larval parasitoids successfully employed in the field for biological suppression of the coconut leaf eating caterpillar, *Opisina arenosella* Walker (Lepidoptera: Xyloryctidae) (Nirula, 1956; Sathiamma *et al.*, 1987). Dharmaraju (1952) reported *Corcyra cephalonica* Staint. (Lepidoptera: Pyralidae) as an alternative host for the laboratory multiplication of this parasitoid. Mohamed *et al.* (1982) and Remadevi *et al.* (1996) reported successful parasitism by *G. nephantidis* on the larvae of *Anigraea albomaculata* Hamps. (Lepidoptera: Noctuidae). In the present study, caterpillars of 23 species of lepidopterans were screened in the laboratory for parasitism by *G. nephantidis*. Detailed studies were conducted in the laboratory to find out the parasitic potential of *G. nephantidis* on *G. mellonella* which was found to be parasitized and the results are compared with those obtained on its natural host, *O. arenosella* and the alternative host, *C. cephalonica*.

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Experiments were conducted in the laboratory at a temperature range of 29–33 °C and relative humidity of 65–77%.

To screen for parasitism by *G. nephantidis*, a total of 23 species of lepidopteran caterpillars were collected from the field and maintained in the laboratory on their respective host plants. Parasitism was studied by exposing all the caterpillars individually to *G. nephantidis* in the laboratory by keeping one larva and a 5-day-old mated female parasitoid in a glass tube 10.5 × 2.5 cm. Ten replicates were maintained for each caterpillar species and they were observed under a stereomicroscope for parasitoid egg laying.

The biological parameters of *G. nephantidis* on *G. mellonella* was studied as follows. *O. arenosella* larvae were collected from infested coconut palms and reared on the coconut leaves to get the optimum stage of parasitization. *C. cephalonica* larvae were reared on semolina and *G. mellonella* on its artificial diet (Singh, 1994). Respective stages of the larvae of *O. arenosella* (Pillai and Nair, 1985), *C. cephalonica* (Dharmaraju and Pradhan, 1976) and late instar stages of *G. mellonella* were used for the experiment. The larvae were kept individually in separate glass tubes (10.5 × 2.5 cm) and a 5-day-old mated female parasitoid was introduced in each tube. The experimental design was CRD. Ten replicates were maintained for each treatment. Observations were recorded on the number and date of egg laying, percentage hatch and survival rate in terms of number of larvae, number of pupae and number of adults emerged. The egg to adult period (total developmental period) and sex ratio of the progeny were also recorded. The data were subjected to statistical analysis using ANOVA.

Of the 23 species of lepidopteran larvae tested, successful parasitization by *G. nephantidis* was recorded on the larvae of the greater wax moth, *Galleria mellonella* L. (Galleridae), besides the usual alternative host, *C. cephalonica* (Pyralidae). Larvae of *Herculia nigrivita* (Pyralidae) (the dry leaf eating caterpillar of coconut) and *Sylepta derogata* (Pyralidae) (a pest of bhindi) were successfully stung and paralyzed by the parasitoid and eggs were laid on them, but the parasitoid failed to complete the development as the host larvae got decayed or dried up within two days. Other species on which no parasitization occurred were *Amata passalis* (Fab.) (Arctidae); *Conthyela rotunda* Hamp. and *Latoia lepida* Cram. (Cochlidiidae); *Gangara thyrsis* Moore, and *Suastus gremius* Fb. (Hesperiidae); *Anadevidia peponis* (Fb.), *Antoba olevaceae* Wlk., *Helicoverpa armigera* Hb., *Spodoptera litura* (Fb.) and *Turnaca acuta* W. (Noctuidae); *Catopsilia crocale* Cramer (Pieridae); *Cnaphalocrocis medinalis* Guen., *Diaphania indica* Saund., *Glyphodes glauculalis* Gr., *Leucinodes orbonalis* Gue., *Pilocrocis milvinalis*, *Psara basalis* F., and *P. bipunctalis* Fb., (Pyralidae); and *Acherontia styx* Westw. (Sphingidae).

The biological parameters of *G. nephantidis viz.*, the number of eggs laid/host larva, number of adults which successfully completed development, total developmental period and sex ratio of the progeny did not show any significant difference among the hosts (Table 1). The oviposition behaviour of the parasitoid on *G. mellonella* was very much similar to that on other hosts as reported by Remadevi *et al.* (1978).

TABLE 1. Comparison of the biological parameters of *G. nephantidis* on three host caterpillars

Host larva	Biological parameters of *G. nephantidis*						
	No. of eggs/host	No. of larvae	No. of pupae	No. of adults	Total develop-mental period	Progeny	
						No. of males	No. of females
O. arenosella	11.56± 2.29 (3.459)	10.44± 4.53 (3.176)	10.44± 4.53 (3.176)	10.44± 4.53 (3.176)	10.12± 0.35 (3.259)	1.11± 0.60 (1.246)	9.33± 4.03 (3.014)
C. cephalonica	10.3± 2.91 (3.26)	9.3± 2.79 (3.104)	9.3± 2.79 (3.104)	9.3± 2.79 (3.104)	10.3± 0.48 (3.286)	1.1± 0.57 (1.244)	8.2± 2.61 (2.92)
G. mellonella	10± 2.4 (3.219)	8.33± 4.33 (2.833)	8± 4.12 (2.782)	7.2± 4.11 (2.634)	11.12± 1.81 (3.4)	1.11± 0.60 (1.246)	6.11± 3.72 (2.427)

Figures in parentheses are square root transformed values. None of the differences between host larvae were significant at $P = 0.05$.

The biological parameters of *G. nephantidis* reared on *G. mellonella* were at par with both the known hosts of the parasitoid *viz.*, *O. arenosella* and *C. cephalonica*. These observations suggest the possibility of using *G. mellonella* larvae for the mass multiplication of the parasitoid in the laboratory, since these larvae can be easily reared on artificial diet.

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Studies on the biology of safflower capsule fly, *Acanthiophilus helianthi* (Rossi.)

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ABSTRACT: Biology of safflower capsule fly, *Acanthiophilus helianthi* is reported after conducting an experiment in the laboratory. The total life cycle of this fly was completed in 20.5–31.0 days, longevity of adults was for 5–12 days. On an average about 9–30 eggs per female were laid in their whole life. Larval period lasts for 6–11 days and pupal period lasts for about 6–9 days.

KEYWORDS: Biology, safflower capsule fly, *Acanthiophilus helianthi*

Safflower, *Carthamus tinctorius* Linn. is one of the important winter season rainfed oilseed crop, but is also grown under irrigated conditions in some area. The crop is mainly cultivated for its seeds which yields a good quality oil, as well as for extraction of a dye from its flowers. The crop is attacked by the various insect pests. Among them capsule fly (*Acanthiophilus helianthi* Rossi) cause considerable loss to the safflower crop. According to Pruthi and Bhatia (1940) this pest was found to cause the damage to the extent of 15–45 per cent.

In Rajasthan, this crop is recently introduced and grown mainly as rainfed crop. Not much work on the biology of this pest attacking safflower crop has been carried out, therefore the present investigation was undertaken.

Studies were carried out in Department of Entomology, Rajasthan College of Agriculture, Udaipur. Pods, damaged by the fly and having black pupae collected from the field were kept in laboratory in jars for adult emergence. The newly emerged adults were collected with an aspirator within 24 h and were released in cages covering the undamaged newly formed capsules in field. Before releasing the adult flies five plants per plot were selected randomly and tagged. From each tagged plant branches with sufficient number of newly formed undamaged pods were chosen. Damaged pod if any was removed before caging.

In each cage 40–50 adult flies collected from laboratory were released with the help of aspirator. These flies were allowed to lay eggs in the caged pods for 24 h and after

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that the cage and flies were removed. The pods were tagged. To study the number of eggs laid in each pod and the incubation period, the pods were plucked and taken to laboratory. The pods were dissected and examined under the binocular microscope. Fifteen pods were dissected and kept in small jars, in which proper humidity was maintained. The eggs were observed every 12 h and hatching was noted.

To know the larval period, about 15 tagged pods were picked every day from the field from different plots and dissected in the laboratory. The practice was followed till the pupae were observed. The pupae were kept in a jar and observed daily to assess the pupal period. The adults emerging from these pupae were kept in a separate jars and were fed with 5 per cent sugar solution to known the longevity. Measurements of different life stages were taken with the help of a micrometer.

A single female was found to lay an average of 19.33 ± 8.54 eggs. These eggs were 1.19 ± 0.07 mm long and 0.29 ± 0.08 mm broad. The incubation period was 1.17 ± 0.24 days. The newly hatched maggots were white with a slight pink colour. Each maggot was 12-segmented measuring about 5.17 ± 0.52 mm in length and 1.51 ± 0.09 mm in width. The larval period was 7.73 ± 1.71 days. Pupation could take place inside the flower buds. Pupae were barrel shaped and black in colour measuring about 2.46 ± 0.12 mm long and 1.75 ± 0.09 mm broad. Average duration of pupal stage was 7.27 ± 1.03 days. Adult fly was 8.27 ± 0.62 mm long and 3.01 ± 0.12 mm broad. The life cycle was completed in 26.37 ± 3.01 days and the mean adult longevity was observed to be 10.20 ± 1.93 days.

Not much work has been reported on the biology of capsule fly, *A. helianthi*. The incubation period, larval period and pupal period, and egg laying in clusters of 6–24 were close to earlier report of Pruthi and Bhatia (1940).

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Effect of temperature on food and water consumption of *Rhynocoris marginatus* (Hemiptera: Reduviidae)

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ABSTRACT: Effect of various temperatures (20, 22.5, 25, 27.5, 30 and 32.5 °C) on the water loss (dehydration), water consumption and predatory efficiency of *Rhynocoris marginatus* (Fabricius) adults was studied. Water loss and water consumption were maximum and minimum at 32.5 and 27.5 °C, respectively. The temperature was positively correlated with water loss, water consumption and feeding potential.

KEYWORDS: Thermal stress, *Rhynocoris marginatus*, biocontrol agent, water consumption

Rhynocoris marginatus (Fab.) is a predator found in the agroecosystems of groundnut, cotton and soybean and also in semi-arid, scrub jungle and forest (Sahayaraj, 2002). It has been well explored as a predator of more than 20 insect pests of agricultural crops (Ambrose, 1999; Sahayaraj *et al.*, 2002). Influence of temperature on the biology (Tawfik *et al.*, 1983) and egg hatching (Sahayaraj and Paulraj, 2001) of reduviids have been studied. For the successful mass rearing of this reduviid predator it is an urgent need to know the effect of temperature on the predatory efficiency. This aspect has been studied in the present investigation.

Ten-days-old *R. marginatus* adults of similar weights (133.9 mg) were introduced into plastic vials (30 ml capacity) and starved for 24 h before the tests. The starved insects were weighed prior to the experiment and introduced into the environmental chamber (Remi) maintaining varying temperatures *viz.*, 20, 22.5, 25, 27.5, 30 and 32.5 °C. Under each temperature, twenty replicates (10 each of male and female) were maintained. The predators were re-weighed after 24 hr to confirm the dehydration if any. After 24 hr each category was divided into two groups. One group was used to find out the water consumption and another group was used to find out the prey consumption. For assessing water consumption, five mg of cotton swab was soaked

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TABLE 1. Effect of temperature on dehydration and predation efficiency of *R. marginatus*

Temperature °C	Water loss	Water consumed (mg)	No. of prey consumed	Amount of prey consumed (mg)	Predator attack efficiency
20.0	2.06	13.55	2.35	22.36	50
22.5	2.72	10.08	2.40	26.58	60
25.0	1.78	8.72	2.45	27.62	70
27.5	0.52	1.58	2.53	29.39	80
30.0	2.85	6.69	2.75	30.86	100
32.5	3.74	23.04	3.20	33.15	100

with one ml of water and placed at the bottom of the vial. Then the vials were placed into the environmental chamber maintained at different temperatures. After 24 hr the predator was re-weighed and the water consumption was assessed. For the latter group, five fourth instar *Corcyra cephalonica* were provided and subjected to the chamber separately. In the second category, the number and amount of prey consumed by the predator were observed. Furthermore the number of predators attacking the prey was also observed and represented as predator attack efficiency.

The data presented in Table 1 reveal that dehydration and water consumption were maximum and minimum when *R. marginatus* was subjected to 32.5 and 27.5 °C, respectively. There was no statistically significant ($P = 0.05$) correlation between temperature and dehydration ($r = 0.36$) and water consumption ($r = 0.22$). The water consumption (23.04 mg) exceeded water loss (3.74 mg) and significant relationship ($P < 0.05$) was noticed between dehydration and water consumption ($r = 0.8$).

Temperature influenced the food consumption of this predator. The maximum food consumption was observed at 30 and 32.5 °C. The rate of change of prey consumption was much slower at lower temperature. The number and amount of prey consumed by *R. marginatus* increased with increasing temperature from 20 to 32.5 °C. As the temperature increases the physiological activities like movements and digestion also increase. At the lowest temperature the predator attack efficiency was reduced to 50%. There was a significant ($P < 0.05$) positive correlation between the temperature and number ($r = 0.91$) and amount ($r = 0.91$) of the prey consumed. These results are in conformity with observations of Awan (1988) and Usha Rani (1992).

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Survey for natural enemies of *Galleria mellonella* and cross infectivity of its nucleopolyhedrovirus

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ABSTRACT: The survey for the incidence of the greater wax moth, in bee colonies of *Apis cerana* in Karnataka revealed some degree of infestation in all the inspected colonies. Among the natural enemies of the wax moth, two entomopathogens, a nucleopolyhedrovirus (NPV) and a bacterium, and two larval parasitoids, *Antrocephalus galleriae* and *Apanteles galleriae* Wilkinson, were isolated. The parasitoids were more prevalent than the pathogens and seemed to keep the wax moth population under check. Studies on the cross infectivity of *Galleria mellonella* NPV to rice moth *Corcyra cephalonica* reveals the high susceptibility of *C. cephalonica*. When *G. mellonella* NPV was administered @1.7×10^6 POBs/ml, to the second instar larvae of mulberry silkworm *Bombyx mori* (KJ race) it did not cause any mortality to *B. mori*. Similarly the *G. mellonella* NPV was found to be safe to two species of honeybees *viz.*, *A. cerana* and *A. mellifera* and also to a general predator *Chryosoperla carnea*.

KEYWORDS: *Galleria mellonella*, nucleopolyhedrovirus, cross infectivity, natural enemies

The bee keeping industry is threatened by various pests of the honeybee. Among them the problem of the wax moth, *Galleria mellonella*, is more serious in the tropical countries. The present communication deals with survey for natural enemies of *G. mellonella*, occurrence of nucleopolyhedrovirus and its pathogenicity, cross infectivity and safety towards beneficial and useful insects.

Some of the bee keeping centres maintained by Department of Industries and Commerce, Government of Karnataka and Apiculturists (Bee keepers) in the State were visited for conducting a survey for the incidence of the greater wax moth. All the bee colonies located at GKVK were also examined for the presence of *G. mellonella*. Observations were also made for the occurrence and incidence of *G. mellonella* in apiaries situated in different districts of Karnataka. The wax moth larvae encountered

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were collected, counted and kept under observation. A survey was conducted to isolate the natural enemies of the greater wax moth, *G. mellonella*, in apiaries located in GKVK, Hessaraghatta, Devenahalli and Chettahalli in Bangalore district and at other locations in Karnataka *viz.*, Madikere, Virajpet, Bhagmandala. The live wax moth larvae collected during the survey were placed in plastic containers provided with aerated lids and brought to the laboratory for the emergence of parasitoids. The larvae were also observed for death due to various diseases. Of these pathogens, the nucleopolyhedrovirus (NPV) was selected for further study. Polyhedral occlusion bodies (POBs) of NPV were purified from the diseased larvae of *G. mellonella* by differential centrifugation following the method of Narayanan (1985). Counts of POBs were made by using haemocytometer.

Though the pathogenicity of GmNPV has been reported (Biswas, 2002) its infectivity against other lepidopteran has not been studied. In order to test its cross infectivity, a preliminary cross infectivity study was conducted with NPV of *G. mellonella* (GmNPV) against eight lepidopteran pests (Table 2). Laboratory cultures of different stages of *Helicoverpa armigera*, *Spodoptera litura*, *Corcyra cephalonica*, *Chilo partellus*, *Achaea janata*, *Opisina arenosella*, *Trichoplusia ni* and *Agrotis segetum* were used. *H. armigera*, *S. litura* and *C. partellus* were allowed to feed on artificial diets which were surface contaminated with GmNPV suspension @ 1.7×10^6 POBs/ml. Cabbage leaf discs treated with the virus suspension were fed to *T. ni*, and *A. segetum*. Castor leaf and coconut leaves were treated with virus suspension and fed to *A. janata* and *O. arenosella*, respectively. *C. cephalonica* larvae were fed with broken rice contaminated with 1.7×10^6 POBs/ml and reared on broken rice in corcyra rearing box. Daily observations on the behaviour of the larvae and on the larval mortality were recorded. The cadavers were observed under phase contrast microscope to account for the cause of death.

To find out the safety of GmNPV, a test was carried out against mulberry silkworm, *Bombyx mori* KJ race and the larvae were fed with GmNPV as well as its own virus *viz.*, BmNPV, *B. mori* larvae were treated with virus suspension containing 1.7×10^6 POBs/ml. In the case of honeybee, newly emerged honeybee adults of two different species *viz.*, *Apis mellifera* and *Apis cerana* which were obtained from the Apiary, UAS, Bangalore, were provided with 1 ml of virus (1.7×10^6 POBs/ml) suspension per 10 ml of honey solution. Adults treated as above with only honey solution served as control. Observation on larval weight and adult emergence was made in each treatment. In case of general predator *Chysoperla carnea* the corcyra eggs were contaminated with GmNPV @1.7×10^6 POBs/ml and fed to *C. carnea*.

The survey carried out in different locations in Karnataka revealed the presence of two parasitoids and two pathogens in populations of *G. mellonella* in the inspected colonies of *A. cerana* (Table 1). The 18% disease incidence in GKVK was mainly due to bacterial pathogen of *Bacillus* sp. whereas the 27% mortality at Chettahalli was due to bacterial and viral combination. The parasitoids *Antrocephalus galleriae* (Hymenoptera: Chalcididae) and *Apanteles galleria* (Hymenoptera: Braconidae) were more prevalent than the pathogens and seemed to keep the wax moth population under

TABLE 1. Presence of natural enemies in *G. mellonella* collected from different localities

Date of collection	Place of collection	No. of larvae collected	% parasitisation	% of disease incidence
03.12.99	GKVK	80	12	18
07.12.99	Hessaraghatta	48	15	–
07.12.99	Chettahalli	55	10	27
11.12.99	Devenahalli	50	8	–
13.12.99	Madikere	50	8	–
13.12.99	Virajpet	65	11	–
13.12.99	Bhagamandala	40	6	–

TABLE 2. Cross infectivity of *G. mellonella* NPV

Insects tested	Stages treated (larval instar)	No. tested	% mortality	Incubation period (days)
C. cephalonica	II	50	78	5
H. armigera	II and III	25 + 25	25	6
S. litura	II	55	00	–
C. partellus	II and III	25 + 25	00	–
T. ni	III and IV	25 + 25	00	–
A. janata	II	50	00	–
O. arenosella	II and III	25 + 25	00	–
A. segetum	II	45	00	–

check in natural colonies as well as in a few apiaries. Pathogens were not as widespread as the parasitoids and the infestation levels were not high enough to be a serious threat to the wax moth larval population. This is probably because any wax moth larvae weakened or killed by disease would be invariably removed from the colony by the worker bees thus removing the disease inoculum and preventing its spread among the surviving larvae.

The GmNPV is an occluded baculovirus and can be easily distinguished by its typical cuboidal shaped inclusion bodies. The polyhedra are large and thus could be easily seen even under low power (40×) with a light microscope (Narayanan, 1998). Studies on the cross-infectivity of the GmNPV has shown that among the insect pests tested, larvae of *C. cephalonica* was highly susceptible to the GmNPV recording 78% mortality. On the other hand, when *H. armigera* was challenged with heterologus NPV *viz.*, NPV of *G. mellonella*, only 25 per cent mortality resulted (Table 2). This low mortality may be due to either contamination or due to the inducement of latent *H. armigera* NPV into frank by GmNPV. The activation of such occult nucleopolyhedroviruses by foreign baculovirus has been reported earlier (Longworth and Cunningham, 1968; Hughes *et al.*, 1993). Further, the progeny virus from *H. armigera* killed after dosing GmNPV revealed the small and more or less round shaped

TABLE 3. Safety test of *G. mellonella* NPV to silkworm, *B. mori* (KJ race), honeybee adults and green lacewing, *C. carnea*

Treatment	Av. larval wt. (mg)	Larval/ Adult* duration (days)	No. treated	Adult emergence (%)
B. mori treated with BmNPV	5.93	20	50	80
B. mori treated with GmNPV	7.72	17	50	20
Control (*B. mori*)	8.29	17	50	85
GmNPV treated *C. cephalonica* eggs and fed to *C. carnea*	0.0272	18	30	100
Untreated *C. cephalonica* eggs and fed to *C. carnea*	0.0268	17	30	100
**A. cerana* treated with GmNPV	—	7	60	—
*Control	—	8	60	—
**A. mellifera* treated with GmNPV	—	8	60	—
*Control	—	7	60	—

POBs of HaNPV unlike that of GmNPV whose POBs are characteristically cuboidal in nature (Narayanan, 1998). The other insects were not susceptible. Pupation and adult emergence were found to be normal. The GmNPV had obviously triggered expression of a latent virus infection in *H. armigera* larvae.

B. mori larvae treated with its own NPV acting as positive control, showed 80% mortality, thus confirming the virulence of the BmNPV used in the experiment (Table 3). None of honeybee adults, *A. cerana* and *A. mellifera* showed any mortality due to viral infection. Similarly none of the green lacewing larvae, *C. carnea*, which were fed with GmNPV contaminated *C. cephalonica* eggs showed any mortality due to viral infection. Treated *C. carnea* larvae completed their life cycle normally as compared to control (Table 3). Though the occurrence of nucleopolyhedrovirus from *G. mellonella* has been reported (Narayanan, 1998) its cross infectivity has been studied. From the present results it is evident that though GmNPV is cross infective to *C. cephalonica* its safety to non-targeted mulberry silk worm, *B. mori*, honeybees like *A. cerana* and *A. mellifera* and to a general predator *C. carnea* showed the future possibility of using GmNPV for the control of *G. mellonella* in an integrated control programme.

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Mosquito fauna of the forested areas of Doon valley, (UP) India

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ABSTRACT: Density patterns of 13 *Anopheline* species along with two species of *Aedes* and *Culex* each collected between January 1995 to December 1997 from four resting places *viz.*, human indoor, human outdoor, animal cattle shed and mixed dwelling in forested areas of Doon Valley are given.

KEYWORDS: Mosquito fauna, Dehra Dun, *Anopheles*, *Aedes*, *Culex*

Mosquitoes have a worldwide distribution occurring throughout the tropical and temperature regions. The available records show that they are found at elevations of 5500 m and in mines at the depth of 1250 m below the sea level. The mosquito fauna of Dehra Dun Valley was first surveyed by Thomson (1903, 1909) and Wattal *et al.* (1958) collected 25 species from this region. The entomological survey of this region was continued by Wattal and co-workers (Wattal and Tandon, 1965; Wattal and Kalra, 1961; Kalra and Wattal, 1965). Later on, Bhat (1975) undertook an intensive survey of haematophagous arthropods in the Himalayan region of Uttar Pradesh, including the Doon Valley and recorded 63 species belonging to 9 genera of mosquitoes. After a gap of about 15 years, again the Dehra Dun region was explored so as to add more information about the occurrence of mosquitoes (Srivastava and Jauhari, 1992a,b; Jauhari *et al.*, 1992; Singh *et al.*, 1994; Jauhari *et al.*, 1995a,b).

The district Dehra Dun, located in the Garhwal region of Western Uttar Pradesh (Now in Uttaranchal) comprise two distinct tracts—the Doon proper and Valley of Dehra, and Jounsar Babar, a more remote subdivision originally unconnected with the former. Doon is really composed of two valleys—the one slopping down to the Jamuna on the North West, the other to the Ganges on the South East. Their north eastern and south western boundaries are the Himalayan mountains and Shiwalik hills respectively.

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TABLE 1. Mosquito density at Dehra Dun Valley during January 1995 to December 1997

Mosquito Species	Mean number of mosquitos caught per man hour in each habitat									
	Human indoor		Human outdoor		Animal cattle shed		Mixed dwelling		Total	
	æ	ß	æ	ß	æ	ß	æ	ß	æ	ß
An. aconitus	0	0								
An. fluviatilis	0	0	0.01	1.03	0.07	1.20	0.08	2.04	0.07	1.67
An. varuna	0	0	0.01	0.07	0.03	0.04	0.02	0.10	0.02	0.08
An. minimus	0	0	0	0	0	0.01	0.01	0.26	0.01	0.17
An. culicifacies	1.73	23.26	0.89	18.10	0.69	11.51	0.69	11.30	0.77	12.82
An. pulcherrimus	0	0	0	0	0	0.22	0.01	0.12	0.01	0.12
An. stephensi	0	0.23	0.11	0.26	0.05	3.20	0.40	4.07	0.29	3.23
An. maculatus	0	0	0	0.23	0	0.11	0.01	0.24	0.01	0.21
An. annularis	0	0.03	0	0.03	0.01	0.25	0.01	0.36	0.01	0.28
An. subpictus	1.00	18.93	0.35	7.52	0.67	10.76	1.09	12.65	0.92	11.94
An. vagus	0	0	0	0	0	0	0.01	0.29	0.01	0.19
An. splendidus	0	0	0	0	0.06	0.30	0.02	0.46	0.03	0.34
An. hyrcanus gr.	0	0	0	0	0.03	1.97	0.02	0.08	0.02	0.30
Ae. aegypti	0	0	0	0	0.06	0.63	0	0	0.01	0.11
Ae. albopictus	0	0	0	0	0.09	3.29	0.09	0.88	0.07	1.15
Cx. quinquefasciatus	1.60	17.26	0.51	6.19	0.70	10.36	0.45	7.32	0.56	8.17
Cx. bravipalpis	0	0	0	0	0.47	7.63	0.10	2.37	0.15	2.86
Man Hours devoted for collection	30		84		110		406		630	
No. of specimens for total Man Hour	130–1792		160–2817		328–5688		1267–17399		1885–27696	
No. of species	5		9		16		16		17	
Percentage*	6.50		10.06		20.34		63.10		100	

*Percentage composition of mosquito in each habitat

For the present study the following localities *viz.*, Sahastradhara, Malsi deer park, Mohobawala, Lacchiwala and Kaulagarh situated at forested areas of Doon Valley and having different attitudes have been selected.

Resting collection of mosquitoes was carried out from human indoor, human outdoor, animal cattle shed and mixed dwelling during the morning hours (0600 to 0900 hrs) using torch light and aspirator. Soon after collection and narcotization of the mosquitoes, the samples were brought to the laboratory and identified using the keys of Wattal and Kalra (1961), Knight and Stone (1977), Das *et al.* (1990) and Nagpal and Sharma (1995).

A detailed survey of the breeding sites was made in the selected localities which mainly comprises of tanks, ponds, drains, pits, streams, canals, containers and tree holes. Larval collection was made using larval net/dipper/pipette as adopted by WHO (1975) and also according to the habitat. After collection the larvae were reared in the laboratory in separate trays according to the habitat and batches, and the emerged adults were later identified.

TABLE 2. Composition of immature mosquitoes in different breeding habitats of Doon Valley during January 1995 to December 1997

Mosquito species	Tanks	Habitats							
		Ponds	Drains	Pits	Streams	Canals	Containers	Tree holes[@]	Total
An. aconitus	78	252				6			
	(1.75)*	(10.76)	0	0	0	(0.34)	0	0	336
An. fluviatilis	216			345	273	627			
	(4.86)	0	0	(11.00)	(15.00)	(36.03)	0	0	1461
An. varuna	21	03		15		36			
	(0.47)	(0.13)	0	(0.48)	0	(2.06)	0	0	75
An. minimus			63	141	36				
	0	0	(3.78)	(4.50)	(1.98)	0	0	0	240
An. culicifacies	420	324	234	279	276	621			
	(9.45)	(13.83)	(14.05)	(8.90)	(15.16)	(35.69)	0	0	2154
An. pulcherrimus		27		129	27				
	0	(1.15)	0	(4.11)	(1.48)	0	0	0	183
An. stephensi	300	207	129	216	129	12	816		
	(6.75)	(8.83)	(7.75)	(6.89)	(7.08)	(0.69)	(31.55)	0	1809
An. maculatus	42	63	3		393				
	(0.94)	(2.69)	(0.18)	0	(21.58)	0	0	0	501
An. annularis	153	75		129	276				
	(3.44)	(3.20)	0	(4.11)	(15.16)	0	0	0	633
An. subpictus	507	639	255	432	267	369	135		
	(11.40)	(27.27)	(15.32)	(13.77)	(14.66)	(21.21)	(5.22)	0	2604
An. vagus	21	96	3	27	63				
	(0.47)	(4.09)	(0.18)	(0.86)	(3.46)	0	0	0	210
An. splendidus	222	21	15	303	36	6			
	(4.99)	(0.90)	(0.90)	(9.66)	(1.98)	(0.34)	0	0	603
An. hyrcanus gr.	306	45	6	126					
	(6.88)	(1.92)	(0.36)	(4.01)	0	0	0	0	483
Ae. aegypti			21	27	39	63	651	144	
	0	0	(1.26)	(0.86)	(2.14)	(3.62)	(24.17)	(32.0)	945
Ae. albopictus	36	15			06		921	306	
	(0.81)	(0.64)	0	0	(0.33)	0	(35.61)	(68.0)	1284
Cx. quinquefasciatus	1221	516	915	333			36		
	(27.46)	(22.02)	(55.00)	(10.61)	0	0	(1.40)	0	3021
Cx. bravipalpis	903	60	21	636			27		
	(20.31)	(2.56)	(1.26)	(20.27)	0	0	(1.04)	0	1647
Total no. of samples	662	546	799	1089	550	538	918	631	5723
Percentage positive	12.84	14.47	9.26	14.05	11.64	8.14	6.32	5.86	10.36
No. of species	14	14	11	14	12	8	6	2	17
Mean no. of larvae/ dip/habitat	0.45	0.28	0.14	0.58	0.22	0.21	4.02[#]	0.71[@]	0.38
Total number of specimens	4446	2343	1665	3138	1821	1740	2586	450	18189

Figures in parenthesis indicates percentage composition.
In each column, the figures in parentheses indicate the percentage of that species out of all the mosquitoes collected from the same habitat.
#Mean number of larvae per house (Laral Density Index) [@]Mean number of larvae in each tree hole

During the study period i.e. January 1995 to December 1997 a total of 29581 mosquitoes have been collected, out of which *Anopheles* sp. comprises a maximum of 21333 specimens followed by *Culex* (7401) and *Aedes* sp. (847) respectively (Table 1). The male–female ratio was up to 1:15.56 for *Culex*; 1:14.69 for *Aedes* and 1:14.41 for *Anopheles*. The adult female *Anopheline* represents 13 different species

TABLE 3. Percentage of female mosquitoes with different abdominal conditions (among some anopheline species)

Species	Place	Number dissected	Abdominal condition of mosquitoes			
			Unfed	Fully fed	Semi gravid	Gravid
An. aconitus	Indoor	[1](113) 96	7.29	26.04	51.04	15.63
	Outdoor	(06) 6	16.67	33.33	50.00	—
An. fluviatillis	Indoor	(965) 872	6.89	36.35	45.07	11.70
	Outdoor	(87) 53	7.55	58.50	18.87	15.10
An. varuna	Indoor	(47) 39	—	32.46	53.85	7.70
	Outdoor	(06) 4	—	25.00	75.00	—
An. minimus	Indoor	(110) 81	13.58	40.74	35.80	9.88
	Outdoor	(00) 00	—	—	—	—
An. culicifacies	Indoor	(6558) 5016	1.97	20.04	56.00	21.99
	Outdoor	(1521) 1011	40.65	15.03	17.01	27.30
An. stephensi	Indoor	(2014) 1781	6.85	47.67	20.89	24.60
	Outdoor	(22) 15	—	26.67	53.33	20.00
An. maculatus	Indoor	(113) 100	20.00	60.00	20.00	—
	Outdoor	(20) 17	11.76	23.53	41.18	23.53
An. annularis	Indoor	(177) 92	15.22	19.57	48.91	16.30
	Outdoor	(03) 00				
Total		(11757) 9183	8.18	27.40	42.92	21.51

[1] Figures in paranthesis indicates total collection of female anophelines.

viz., *An. aconitus*, *An. fluviatilis*, *An. varuna*, *An. minimus*, *An. culicifacies*, *An. pulcherrimus*, *An. stephensi*, *An. maculatus*, *An. annularis*, *An. subpictus*, *An. vagus*, *An. splendidus* and *An. hyrcanus* group while *Aedes* includes *Ae. aegypti* and *Ae. albopictus* and for *Culex* species *Cx. quinquefasciatus* and *Cx. brevipalpis*. Out of a total of 630 man hour the order of species dominance found among the *anophelines* was *An. culicifacies* (40.14%), *An. subpictus* (37.97%) and *An. stephensi* (10.39%) followed by *An. fluviatilis* (5.13%).

In human dwelling only 4 species of *Anopheles* were present i.e. *An. culicifacies*, *An. stephensi*, *An. annularis* and *An. subpictus* in lesser amount where as *An. subpictus* was predominant in cattle sheds showing highly zoophilic nature followed by *An. culicifacies* which is also a zoophilic, the next species in order of abundance was *An. stephensi* and *An. hyrcanus* group.

Investigation of the *Anopheline* fauna in the forested area of Doon Valley revealed the presence of 11 species *viz.*, *An. culicifacies*, *An. annularis*, *An. fluviatilis*, *An. stephensi*, *An. hyrcanus* group, *An. minimus*, *An. subpictus*, *An. splendidus*, *An. vagus*, *An. aconitus* and *An. maculatus*. It is evident from the data that *An. culicifacies* was predominant in all the resting habitats but maximum number was collected from mixed dwellings. A few specimens of *An. varuna* and *An. pulcherrimus* were found during the whole study period.

Among the breeding sites inspected (tanks, ponds, drains, pits, streams, canals, containers and tree holes), ponds have got the maximum positivity (14.46%) followed by 14.04% for pits and tank (12.87%) among the total samples 546, 1089, 662

TABLE 4. Man hour density of different mosquitoes along with male female ratio in Dehra Dun Valley during January 1995 to December 1997

Mosquito species	Total specimens collected	Per man hour density	Male-female ratio
An. aconitus	134	0.21	1:7.9
An. fluviatilis	1095	1.73	1:23.8
An. varuna	66	0.10	1:3.7
An. minimus	115	0.18	1:18.1
An. culicifacies	8566	13.59	1:16.5
An. pulcherrimus	81	0.12	1:15.2
An. stephensi	2216	3.51	1:11.3
An. maculatus	137	0.21	1:26.4
An. annularis	188	0.29	1:19.8
An. subpictus	8101	12.85	1:12.9
An. vagus	127	0.20	1:20.1
An. splendidus	243	0.38	1:11.7
An. hyrcanus gr.	264	0.41	1:17.8
Ae. aegypti	77	0.12	1:10
Ae. albopictus	770	1.22	1:15.3
Cx. quinquefasciatus	5502	8.73	1:14.6
Cx. brevipalpis	1899	3.01	1:18.9
Anopheles	1333	33.86	1:14.4
Aedes	847	1.34	1:14.6
Culex	7401	11.74	1:15.5

collected respectively. Regarding the mosquito breeding, tank (24.44%) is followed by pit (17.25%) and container (14.22%). Maximum species (14) of mosquitoes breed in tanks, ponds and pits whereas in tree holes only the two species of *Aedes* i.e. *Ae. aegypti* and *Ae. albopictus* were found breeding. Anopheline mosquito immatures were encountered mostly from tanks (20.24%); pits (18.97%) and streams (15.73%) (Table 2). In all, a total of 18189 immatures have been collected in which comprises of 62.08%, *Culex* 25.66% and *Aedes* 12.25%.

Among a total of 13 species of only eight species (recognised vectors) *viz.*, *An. aconitus*, *An. fluviatilis*, *An. varuna*, *An. minimus*, *An. culicifacies*, *An. stephensi*, *An. maculatus* and *An. annularis* were studied for abdominal condition and found that 8.18% of the females were unfed, 27.40% fullyfed, 42.92% semi gravid and 21.51% it was gravid (Table 3).

The total Man Houer Deinsity of the different anopheline species during the study period is given in Table 4 along with male–female ratios. *An. culicifacies* has the maximum MHD (13.59) followed by *An. subpictus* (12.85) and *An. stephensi* (3.51).

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3rd GLOBAL MEET ON PARASITIC DISEASES

BANGALORE UNIVERSITY, BANGALORE, INDIA

JANUARY 12–16, 2004

NEW ANNOUNCEMENT AND CALL FOR ABSTRACT

Due to unavoidable circumstances the 3rd Global Meet on Parasitic Diseases which was scheduled to be held on 25–29 November 2003 is postponed to January 12–16, 2004. Consequently, the last date to receive the abstract of the research paper is postponed till 30th November, 2003. The Meet will focus on 'Emerging Parasitic Diseases and their Control' and will cover the following topics. Taxonomy, Life cycle and Parasitology; Molecular and Cell biology; Genetics and Biotechnology; Diagnosis and Clinical aspects; Morphology and ultra structure; Pathogenesis and Epidemiology; Immunology; Immune response, Vaccines; Drugs, Chemotherapy and Drug resistance; Vector Biology and Vector control; Biochemistry, Physiology and Nutrition; Parasite cultivation, Animal models and colonization; Host–parasite relationship; Ecology and Environmental Parasitology; Environmental control and Management; Biodiversity of Parasite and Vectors; Impact of Urbanization and Parasitic diseases; Techniques; Zoonosis; Sociology and Economics; Information, Education and Communication; Modeling and Diseases control; Public Health; Biotechnological tools in the control of both vectors and parasites; and Plant and Soil nematodes.

Interested persons are invited to submit abstracts latest by **30 November, 2003**.

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